DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 365

GROUND WATER IN SOUTHEASTERN NEVADA

BY

EVERETT CARPENTER

Monograph

WASHINGTON
GOVERNMENT PRINTING OFFICE
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INTRODUCTION.

LOCATION AND AREA.

The area covered by this report lies in southeastern Nevada and comprises about 17,000 square miles, of which about 6,000 square miles is in Clark County, 8,500 in Lincoln County, 300 in White Pine County, and 2,000 in Nye County. (See fig. 1.) The area thus covered is about the size of Massachusetts and New Hampshire combined. The San Pedro, Los Angeles & Salt Lake Railroad, commonly known as the Salt Lake route, crosses the eastern and southern parts of the area, passing through Caliente, Moapa, and Las Vegas. Two branch roads connect with the main line, one extending from Pioche to Caliente and another from Moapa to St. Thomas. The Las Vegas & Tonopah Railroad, which is subsidiary to the Salt Lake route, extends from Las Vegas northwestward to Goldfield.

PURPOSE OF INVESTIGATION.

The agricultural development of an arid region, such as is covered by this report, is dependent on the water supply available for irrigation and for domestic use. Large areas of good soil lie idle for want of water to make them productive, and most of the water that falls as rain or snow is dissipated and produces very little vegetation that is of economic value. A large amount of water percolates through the ground to the streams or valley floors, from which most of it is removed by evaporation. In some places this water can be intercepted in its course through the ground and used for domestic purposes, for watering live stock, or for irrigation.

The need of more watering places on the range has long been felt, and recently the demand for information in regard to available supplies of ground water in Nevada has been increased by the agricultural, mining, and industrial development of the State. The springing up and rapid growth of many new mining camps has caused a new and imperative demand for water for domestic use and for mining and milling; the building of railroads has made necessary new supplies for locomotive and domestic use; and the estab-

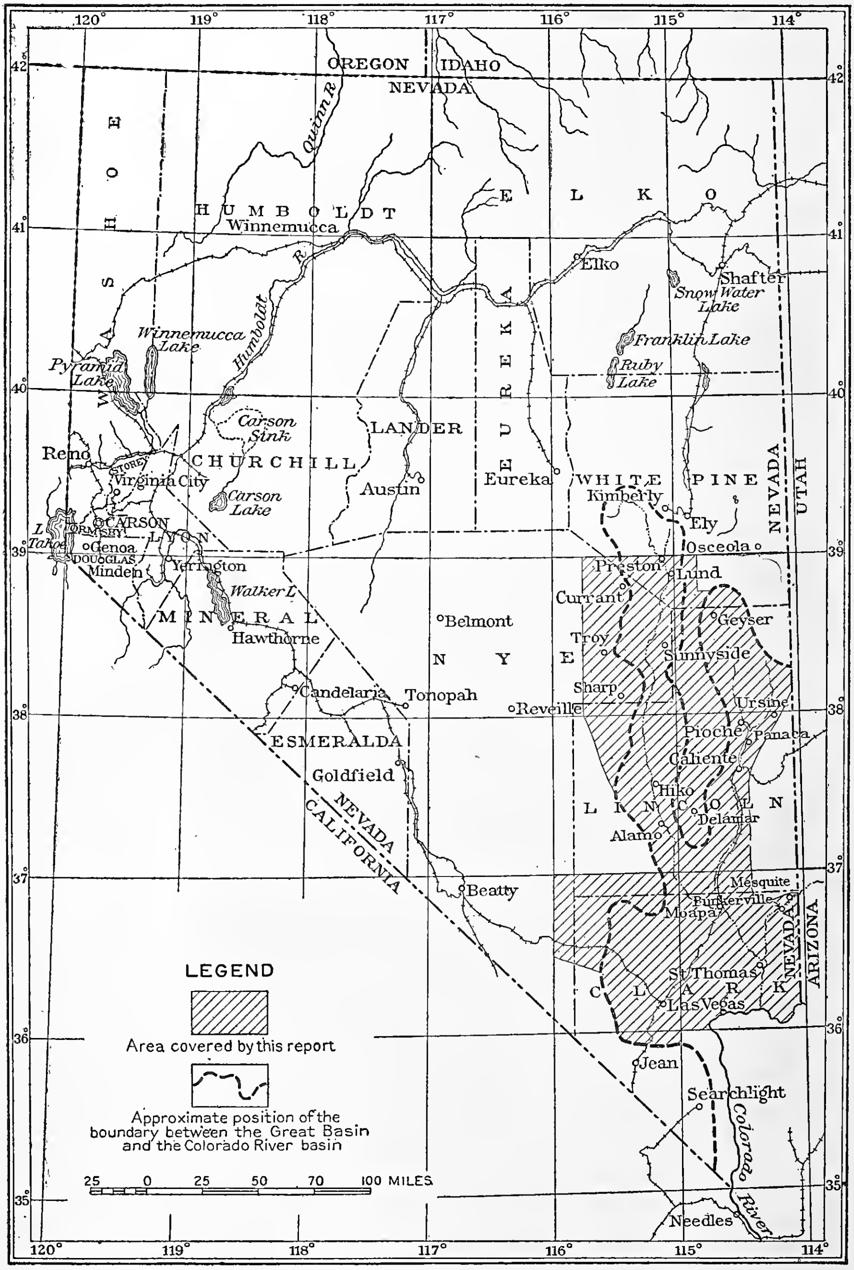

FIGURE 1.—Map of Nevada showing the area investigated and approximate position of boundary between Great Basin and Colorado River basin.

lishment of dry farms has created a need for new water supplies for domestic purposes, for stock watering, and for supplementary irrigation. The enlargement of the agricultural communities and the nearly complete utilization of the stream waters has turned attention to the possible development of underground supplies for irrigation.

In the summer of 1912 the United States Geological Survey, recognizing the value of the underground supplies in the State and the general lack of knowledge about them, began an investigation of southeastern Nevada as part of a comprehensive ground-water survey of the entire State.

ACKNOWLEDGMENTS.

The completeness of such a report as is here presented depends very largely on the information and aid given by the people of the region examined, and the writer desires to express his indebtedness to the many persons who have willingly given data that have been useful in preparing the paper.

GEOGRAPHY.

DRAINAGE.

The area covered by this report lies in two drainage provinces—the Great Basin and Colorado River basin. The boundary between these two provinces has never been accurately mapped. It runs from northeast to southwest in a very irregular course, throwing about one-fourth of the area, comprising Delamar, Bristol, Coal, Garden, Dry Lake, Indian Spring, and Railroad valleys, into the Great Basin, and the other three-fourths, comprising the Meadow, White River, Muddy River, Virgin River, and Las Vegas valleys, into the Colorado River basin. (See fig. 1.)

Two well-defined drainage systems in southeastern Nevada, those of Virgin River and of Las Vegas Wash, are tributary to Colorado River. (See Pl. I, in pocket.) Virgin River rises in southern Utah, flows southwestward across the northwest corner of Arizona, enters Nevada at Mesquite, flows past Bunkerville and St. Thomas, and discharges into Colorado River. The main tributary to this stream is Muddy River, which at present rises in the Moapa Indian Reservation but which in former geologic times had its source many miles to the north in the head of the White River valley. A well-developed and open channel extends from near the town of Preston southward through Pahranagat Valley and into the Muddy River valley. Meadow Valley Wash, the largest affluent of Muddy River, has its source in two forks, which unite north of Panaca. One fork heads in Duck Valley, near Geyser, and the other in Ursine Valley. The

stream is joined at Caliente by Clover Creek, descends steeply toward the south, and discharges into Muddy River below Moapa. Las Vegas Wash is a drainage channel which heads in Las Vegas Valley, for which it is the only outlet. At the present it is dry except in times of great floods, but there is good evidence that at one time it was a stream of considerable size.

White River and Duck valleys seem to have been regarded by the early explorers as having an interior drainage. Capt. G. M. Wheeler,[1] who made the first survey of this area, in speaking of the itinerary of the expedition of 1869, says:

> The principal streams * * * from south to north are Virgin River and Muddy Creek, a tributary heading in Pahranagat Valley, with a small affluent having its source at the head of Cedar [Ursine] Valley near the Utah boundary.

The "small affluent" of which Wheeler speaks is Meadow Valley Wash, which forks at Panaca, one branch heading in Ursine Valley and the other in Duck Valley, in the vicinity of Geyser. The boundary of the Great Basin, as given by Gilbert's map,[2] conforms in general to the area outlined by Wheeler.

Spurr [3] was the first to call attention to the fact that Duck and White River valleys are connected with the ocean by open channels. In speaking of the erosion in the dry valleys of southeastern Nevada he says:[4]

> A large part of Nevada has well-defined valleys forming a part of the Colorado River system, which a week of rain would supply with streams. Meadow Valley, which heads near Pioche, is tributary to the Virgin River, an affluent of the Colorado. For the greater part of the course it is a magnificent canyon, cut sharply in Tertiary lavas and tuffs to a depth which in places reaches 2,000 feet. * * * The canyon is continuous farther north with a typical flat desert valley, called Duck Valley, which extends beyond the thirty-ninth parallel. On the south Meadow Valley is confluent, not far from its end, with the valley of Muddy Creek, in which flow waters derived from a spring. Above the source of the spring a drainage channel extends northward nearly to the latitude of Eureka. * * * In its upper portions it goes by the name of White River.

TOPOGRAPHY.

GENERAL FEATURES.

The most characteristic topographic features of the area covered by this report consist of a series of parallel north-south mountain ranges and intervening broad débris-filled valleys. This type of topography predominates over the Great Basin and adjacent regions and is known as the Basin Range type. These mountain ranges were produced by a system of parallel faults, the strata on one side

[1] Wheeler, Capt. G. M., Geographical report: U. S. Geog. Surveys W. 100th Mer., vol. 1, p. 22, 1889.
[2] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, Pl. II, 1890.
[3] Spurr, J. E., Origin of the Basin ranges: Geol. Soc. America Bull., vol. 12, pp. 217-270, 1901.
[4] Op. cit., p. 252.

of which were uplifted with respect to the strata on the other side. The valleys owe their existence and character to the faulting movements whereby great troughs were formed, and to the arid climate and deficient water supply, as a result of which the sediments washed from the mountains were not carried onward to the sea, as would have been the case in a humid region, but were accumulated in the valley troughs forming the broad and comparatively smooth desert plains that lie between the ranges.

STREAM TOPOGRAPHY.

Since the deformation of the region, running water, resulting from rains or melting snow, has been actively modifying the topography. The faces of the mountain escarpments have been carved into intricately shaped surfaces. The torrential streams which head in the mountains have cut deep canyons and have carried the excavated material into the valleys, which they are gradually filling.

The material thus carried from the mountains and redeposited in the valleys has produced alluvial fans and slopes. In their upper courses the streams have steep gradients and are confined to narrow channels and therefore they erode rapidly, carrying clay, sand, gravel, and bowlders into the valley. Below the mouths of the canyons, however, the narrow channels become broader, the steep gradients become gentler, and the swift currents slacken. The coarse material which the stream has brought from the mountains is deposited and the areas surrounding the mouths of canyons are built up more rapidly than the other parts of the valley, forming conspicuous fans adjacent to the ruts. The stream channels that dissect the face of the mountains are numerous, so that the alluvial fans are so close together that they coalesce and form a fairly uniform surface.

The streams vary in magnitude at different times and the distance to which they carry eroded material is by no means constant. A stream resulting from a heavy downpour may carry large bowlders far into the valley, whereas a stream resulting from a gentle rain may deposit even fine material near the mountains. Moreover, a stream does not build all parts of the slope simultaneously, but fills up in one place until its channel is higher than an adjacent part, when it breaks over and flows across the lower portion. Hence the alluvial slopes are composed of material in all grades of fineness. Since the alluvial slopes are composed largely of coarse material, streams flowing over them generally sink soon after emerging from the canyon.

If no weathering had occurred and no work been done by the streams the relief of the region would be much greater than it is. The mountains would be higher, the valleys would be lower, and the

mountain sides would be steeper. Ever since deformation took place the streams have been tearing down the mountains and building up the valleys. The extent to which the valleys have been filled is not known, but the deepest wells in southeastern Nevada have apparently ended in valley fill.

The processes described are effective in an arid climate, such as exists at present in southeastern Nevada. A period of aridity, however, may be interrupted by a period of relative humidity, during which the intermittent streams emerging from the mountains become persistent. If the valley into which the streams flow is completely surrounded by higher ground a lake is produced, but if the valley is open the water flows out and carries away part of the material already deposited in the valley. A lake in a closed valley may rise until it flows over its containing wall and the outflowing stream may erode a channel in an adjacent valley through which it discharges. Examples of all three conditions are found in southeastern Nevada. The evidence shows that Coal, Bristol, Delamar, and Railroad valleys formerly held lakes that had no outlets; that Duck Valley and the northern part of Las Vegas Valley held lakes which overflowed; and that the White River and Meadow Creek valleys were open troughs through which rather large rivers had their channels.

LAKE TOPOGRAPHY.

The topographic features formed by running water have been modified in a few of the valleys by the waves of ancient lakes. Along the shores of these lakes were formed beaches, terraces, and other shore features not unlike those existing at the margins of modern lakes, though small and inconspicuous in comparison with those exhibited in some other parts of the Great Basin.[1] The most pronounced shore features were formed when the lakes stood at their highest levels, those of less prominence being formed at lower levels.

With the exception of a small amount of erosion on alluvial slopes the topography has undergone only slight modification since the desiccation of the lakes. The bottoms of the closed basins are slowly being built up and the ancient river channels in the open valleys have in many places been partly or wholly blocked by deposits which project as small alluvial cones from the mouths of tributary arroyos.

WIND TOPOGRAPHY.

The wind has been active in reworking the finer sediments that were deposited in the valleys by the processes just described and also in abrading the bedrock formations in exposed places. It did its

[1] Gilbert, G. K., Lake Bonneville: U. S. Geol. Survey Mon. 1, pp. 90–169, 1890. Also Russell, I. C., Geological history of Lake Lahontan: U. S. Geol. Survey Mon. 11, pp. 99–123, 1885.

most conspicuous work in Muddy Valley below Moapa, where it carved intricate pits and holes in the steep cliffs. In many other places the outcropping rocks have been worn smooth by the impact of wind-blown sand. In Las Vegas Valley the numerous sand dunes, found usually on the north sides of the stream channels, were probably formed by the action of the prevailing wind which carried the sand brought down by the storm waters into the vegetation to the north. In some of the valleys good desert "pavements" have been produced by pebbles left at the surface after the finer sediments were carried away by the wind.

VEGETATION.

The native vegetation varies with the ecologic conditions. On the high mountains pine, cedar, and mahogany are the predominating plant species, but these give way to piñon and juniper farther down on the sides of the mountains. The valleys are in general covered by sagebrush, shadscale, creosote, Spanish bayonet, yucca, and other drought-resisting plants. Along the streams and in the shallow-water areas mesquite, rabbit brush, arrow weed, quail brush, cottonwood, and willows are found. Native grasses are found in some localities, especially in places which receive the run-off from the mountains or the discharge from springs.

INDUSTRIAL DEVELOPMENT.

In the early days, before the railroads in this area were built, transportation was here effected by wagons. Building material for St. Thomas was hauled overland from Milford, Utah, and the machinery used in the mines at Pioche was brought from Palisade, Nev., on the Southern Pacific Railroad. The San Pedro, Los Angeles & Salt Lake Railroad was constructed through this part of Nevada in 1904, since which time communication with the outside world has been easier.

Most of the early inhabitants of Nevada were miners and prospectors and therefore congregated in the mining camps. The first active mine in this area was discovered in 1869 at Pioche, which by 1872 became a town of about 10,000 inhabitants. The Delamar mines were opened in 1875 and were in active operation by 1879. Only in the better-watered communities, however, was farming undertaken, and in the area here considered only three localities were so favored. Muddy Valley was settled in 1858 by Mormons but was deserted in 1865, owing to a conflict between the settlers and the Lincoln County authorities, and was not again settled until 1876. Meadow and Ursine valleys were settled by Mormons in 1863 and 1864, respectively, and Pahranagat Valley in about 1880. It was not until recent years that agricultural development was begun in Las Vegas Valley. The first flowing well was sunk in 1906, and

since that time many settlers have come into the valley and about 100 flowing wells have been sunk.

Dry farming has been undertaken in Duck, Ursine, and Meadow valleys, and the results thus far obtained seem to indicate that it may be practiced successfully in parts of some of them. The data in hand, however, do not warrant the belief that it may be practiced in all the valleys nor that good crops can be raised every year in the places where it is now attempted.

The cattle and sheep industry has always been important in this region. So much of the State is remote from the railroads that the ordinary farm products can not be profitably transported to market. Cattle and sheep can, however, be pastured on the range and driven to the railroad at little cost.

CROPS.

The principal crops that can be grown in all the valleys of southeastern Nevada are wheat, oats, Indian corn, alfalfa, rye, potatoes, cantaloupes, watermelons, apples, pears, and garden stuffs. In the southern part of the area, where a subtropical climate prevails, grapes, peaches, pomegranates, and almonds are successfully produced. Until the completion of the San Pedro, Los Angeles & Salt Lake Railroad in 1894 the agricultural communities had no market for their products except a few small mining towns, and hence the principal crops were such as could be profitably fed to stock. Since the completion of the railroad it has been practicable to transport the produce from a part of the region to the cities, and agricultural development has consequently been stimulated. In 1912 a large acreage of cantaloupes in Muddy Valley was reported to have yielded the owners an average of $170 per acre.

The long growing season in southeastern Nevada, the variety of crops that may be grown, and the large yields that are possible furnish ideal conditions for farming in the localities where water for irrigation can be obtained.

GEOLOGY.[1]

The rocks exposed in the large area covered by this report probably range in age from pre-Cambrian to Recent.

Pre-Cambrian igneous rocks and gneiss are found in Boulder Canyon at the south end of the Muddy Range and also at the south end of the Virgin Range.

[1] Summarized in large part from the works of earlier geologists, especially the following:

Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel and adjacent parts of California: U. S. Geol. Survey Bull. 208, 1903.

Wheeler, Capt. G. M., Geology: U. S. Geog. Surveys W. 100th Mer., vol. 3, 1875.

Ball, S. H., A geologic reconnaissance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, 1907.

The Paleozoic formations comprise a great thickness of limestone, sandstone, shale, and quartzite. The most complete section of the beds is found in the Las Vegas Range,[1] where rocks of Cambrian, Ordovician, Silurian, Devonian, and Carboniferous ages are exposed. In many places the Ordovician, Silurian, and Devonian are absent from the Paleozoic section.

Mesozoic formations of limestone, sandstone, clay, conglomerate, and lava, are found in the Spring Mountain and the Muddy ranges. These beds are Jurassic and Triassic in age. Cretaceous rocks are not known to occur in this area.

Sandstone, clay, conglomerate, rhyolite, andesite, and tuff believed to be of Tertiary age are found in the Mormon, Meadow Valley, and Seaman ranges. The beds are well exposed in the Meadow Valley canyon between Moapa and Panaca and in the White River valley in the vicinity of White Rock Spring.

Stream, wind, and lake deposits, consisting of relatively unconsolidated gravel, clay, and sand, occur beneath the valleys. These sediments were the last to be deposited and are of late Tertiary, Pleistocene, and Recent age. They constitute the valley deposits with which the structural troughs are partly filled. Their depth is not known, for no well sunk in them seems to have reached their bottom, not even the Potash well in Railroad Valley, which was sunk to a depth of 1,204 feet.

GEOLOGIC HISTORY.

Cambrian rocks containing marine fossils are found at various localities in this area, and it is therefore certain that this portion of southeastern Nevada was at least partly submerged beneath the sea in Cambrian time. The absence of Ordovician, Silurian, and Devonian rocks over most of the region makes it probable that this area was largely above the sea and was therefore subject to erosion during these periods.

Thick Carboniferous formations containing marine fossils are found in many places, indicating that the area was again submerged in Carboniferous time.

The Mesozoic era is represented in this area by rocks belonging to the Jurassic and Triassic systems only, Cretaceous rocks being absent, and even Jurassic and Triassic rocks are found only in the Muddy and Spring Mountain ranges. It is therefore probable that southeastern Nevada was largely land during Jurassic and Triassic times and that it was wholly land during Cretaceous time.

At the close of the Mesozoic era the Paleozoic and Mesozoic rocks were folded and faulted by movements that probably continued to a

[1] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel: U. S. Geol. Survey Bull. 208, pp. 155-157, 1903.

greater or less degree until very recent time. In the vicinity of Hiko there are fresh fault scarps which affect the valley fill and which have obviously been formed in very late time.

Stratified sedimentary rocks of Tertiary age occupy many of the structural troughs in southeastern Nevada, showing that the region was partly submerged or at least subjected to sedimentation during this time. Great masses of igneous rocks are associated with the sedimentary material, showing that the Tertiary was also a period of great volcanic disturbance. This period was probably one of extensive erosion and of lake deposition. Ball [1] believes that the area to the west, which lies between 36° 30′ and 38° north latitude and between 116° and 117° 30′ west longitude was in Tertiary times the site of a lake that he calls Pahute Lake. Rowe [2] believed that a Tertiary lake lay in Las Vegas Valley, and other valleys may also have contained lakes in this period.

During parts of the Pleistocene epoch the climate in the Great Basin was much more humid than it is now and the closed basins contained rather large lakes. The waters of Great Salt Lake stood about 1,000 feet higher than at present and the Carson Sink was at the bottom of another great lake. This humid period was represented in southeastern Nevada by a number of lakes and streams. Coal, Duck, Bristol, Delamar, Railroad, and Indian Spring valleys and the northern part of Las Vegas Valley contained lakes, and the White River, Pahranagat, Muddy, Meadow, and Las Vegas valleys contained large streams. (See Pl. I.) Three sets of terraces are found in the valleys drained by the tributaries of Colorado River. They are especially well developed in Las Vegas and Meadow valleys, where they show the most conspicuous topographic features. These terraces appear to have been produced by successive stages of filling and erosion and are probably the results of varying climatic conditions in the Pleistocene epoch. The climate during this epoch is believed to have been alternately dry and humid. During the humid stages the valleys were excavated and in the arid stages they were refilled. Lee [3] has shown that the Grand Canyon of the Colorado was formed by three stages of down-cutting separated by stages of nonerosion, and the terraces in the débris-filled valleys of southeastern Nevada may correspond in time with these three stages.

The lake features in the closed valleys show only one period of humidity. Any climatic conditions that would produce erosion in the open valleys would doubtless produce lakes in the closed valleys, but in valleys that contained only small lakes the traces of earlier

[1] Ball, S. H., A geological reconnaissance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, p. 41, 1907.

[2] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel: U. S. Geol. Survey Bull. 208, p. 157, 1903.

[3] Lee, W. T., Geologic reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, 1903.

lakes would doubtless be destroyed or concealed by those of later ones and only those of the most recent lake would probably be preserved. In the Great Salt Lake and Carson basins, however, there is evidence of more than one high-water stage, and these evidences of several stages of humidity are corroborated by the well-known evidences of climatic fluctuations in the glaciated regions.

RAINFALL.

GEOGRAPHIC DISTRIBUTION.

Rainfall data have been collected for the United States Weather Bureau at the stations named in the following table. Two of the stations—Ely and Modena—lie outside of the area here considered, Ely being to the north and Modena to the east.

Annual precipitation (in inches) at seven stations in southeastern Nevada.

Year.	Pioche.	Geyser.	Ely.	Logan.	Las Vegas.	Modena.	Caliente.
1878	8.36						
1879	6.94						
1880	4.67						
1881	5.25						
1882	8.31						
1888	16.72						
1889	27.35		13.54				
1890	16.14		7.16				
1891			18.01				
1892	7.10						
1893			9.14				
1894			16.17				
1895			14.77				
1896			11.82		3.24		
1897			17.20		5.35		
1898			15.06		1.64		
1899			14.35		2.03		
1900			10.47				
1901			11.51			9.24	
1902			10.91			5.09	
1903						6.93	
1904						9.83	
1905		8.26				12.39	
1906	19.15	19.04				19.08	
1907		11.38		7.44		12.80	
1908			7.45	7.51	4.73	16.62	
1909			13.15	8.17		11.49	
1910		1.15	6.62	3.15	2.92	9.50	
1911		1.00	5.00	5.03	[a] 4.70	10.46	6.09
1912		3.05	3.96	3.92	[a] 1.33	10.07	2.98
Average	11.99	7.31	11.46	5.84	3.42	11.12	4.53

[a] Data collected at Jean.

These records are too few and too discontinuous to allow the formation of any but the most general conclusions regarding the geographic distribution of the rainfall. In general more rain falls in the northern part of the area than in the southern part and more in high than in low altitudes. Thus the average annual precipitation is 7.31 inches at Geyser and 11.99 inches at Pioche but only 3.42 inches at Las Vegas and 5.84 inches at Logan. These averages are, however, not very conclusive because they cover different years.

In the arid region the rains often come in the form of "cloud-bursts," in which a large amount of water falls on a small area in a short time.

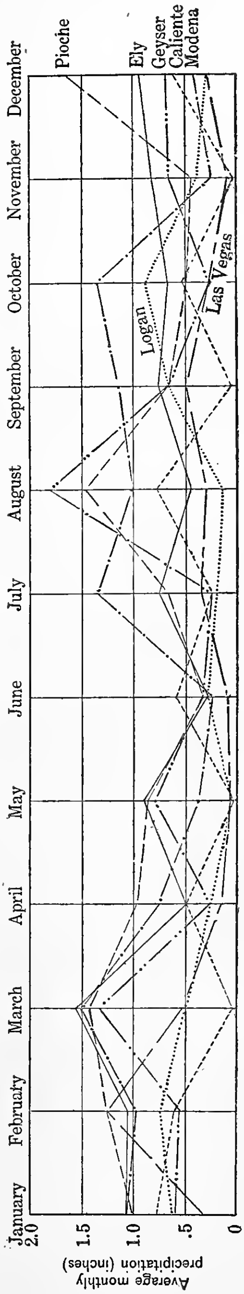

FIGURE 2.—Diagram showing average monthly precipitation at seven stations in southeastern Nevada.

ANNUAL VARIATION.

The precipitation at any station varies from year to year. Thus the records show a range in annual precipitation from 4.67 to 27.35 inches at Pioche; from 1 to 19.04 inches at Geyser; from 3.96 to 18.01 inches at Ely; from 3.15 to 8.17 inches at Logan; from 1.33 to 5.35 inches at Las Vegas; and from 5.09 to 19.08 inches at Modena. The records are not sufficiently extensive to be of service in correlating the variations at different stations.

SEASONAL VARIATION.

The precipitation is not equally distributed throughout the year. In general more rain falls during January, February, and March than during April, May, and June, and more falls during July, August, and September than during October, November, and December. The rains occurring during February and March are usually heavier than those occurring during July, August, and September. (See fig. 2.)

OCCURRENCE OF GROUND WATER.

WATER IN BEDROCK.

Sedimentary rocks.—The indurated sedimentary rocks exposed in this region consist mainly of Paleozoic limestone, quartzite, and shale. Their outcrops are confined to the mountainous areas and are found in most of the mountain ranges. The conglomerates, sandstones, and clays, which belong to the younger systems, are confined to the lower mountains and table-lands, being found in Las Vegas, Muddy, and Virgin valleys and along Meadow Valley Wash.

The Paleozoic quartzites and limestones are generally so compact and so impervious that water can not pass through them except along joints and fracture zones. The conglomerates and sandstones are generally more pervious and unless too firmly cemented allow water to pass through their pore spaces. The shales and clay beds are practically impervious.

If the indurated strata were in a favorable topographic attitude they would doubtless furnish small amounts of water to wells in some localities, but they generally lie in such a position that the water which sinks into them in the mountainous areas is either returned to the surface at places where the strata outcrop or is carried so far below the unconsolidated sediments that it can not be reached except by very deep drilling. Consequently very little water has been obtained by wells sunk into bedrock and but few attempts have been made to obtain water from it.

The mining shafts that have been sunk into the indurated strata to considerable depths have not all obtained water. The shaft at Delamar found no water, although it was sunk to a depth of 1,400 feet, but the workings at Pioche are reported to have been drowned at the 1,100-foot level. The shaft in Jackrabbit mine at Royal goes to a depth of 1,500 feet without finding water.

Igneous rocks.—The igneous rocks include granite, andesite, rhyolite, and tuff. Igneous rocks of Tertiary age occur in large quantities in Meadow Valley, Pahroc, and Hiko ranges, and on both sides of Ursine Valley.

No wells in igneous rocks have been reported, but in some localities small amounts of water no doubt occur in cracks and fissures in these rocks. Seaman, White Rock, and Pahroc springs issue from volcanic tuff and yield small supplies.

Confining function of bedrock.—For the region as a whole the indurated sedimentary and igneous rocks can afford relatively small quantities of ground water. The most important function of these bedrock formations is to close the débris-filled valleys by making their bottoms and sides practically impervious and thus to prevent in large part the downward escape of the water that may be stored in them, making underground reservoirs of the masses of softer deposits above them. Open valleys, like the White River, Pahranagat, and Las Vegas, allow some of the water which they receive to escape, but as their outlets are usually small in comparison with their size the annual increment is always sufficient to replace the loss by seepage. Most of the closed valleys, such as Coal, Dry Lake, Bristol, and Delamar, are higher than the adjacent valleys and lose so much water through fissures in the rocks that their water levels remain far below the surface. It is not likely, however, that all their water escapes or that their unconsolidated sediments are

generally entirely dry. The indurated strata therefore cause an accumulation of water, which may be drawn upon in the low parts of the valleys, and are in this respect of great economic value.

WATER IN UNCONSOLIDATED SEDIMENTS.

Character of sediments.—The sediments that partly fill the structural basins have been derived primarily from the mountains. In a few localities the deposits are composed of volcanic tuff and lava, but these are relatively unimportant. Ever since the great deformation movements that brought about the major relief of the region winds, rains, frosts, and vegetation have been disintegrating the ancient limestones, quartzites, and igneous rocks, and torrents and permanent streams have been carrying away the fragments and redepositing them in the valleys. These processes have given rise on the one hand to fantastically sculptured and serrated peaks and on the other hand to smooth alluvial slopes.

These deposits of clay, sand, gravel, and bowlders are collectively called "unconsolidated sediments" or "valley fill," to differentiate them from the older and much more indurated formations, which outcrop mainly in the mountainous areas and which are collectively called "bedrock." It should be remembered, however, that even the so-called unconsolidated sediments are more or less cemented, as is shown by the fact that many wells in them have stood for a long time without being cased above the water table. In some localities the valley fill has been subjected to metamorphism by the heat of more recent lavas.

The unconsolidated sediments are much more valuable as water-bearing beds than the bedrock formations. The bedrock formations are usually hard, compact, and relatively impervious except for cracks and fissures, and consequently they do not hold much water, but the unconsolidated sediments are usually granular and porous, and unless they are fine grained or clayey they will hold a relatively large amount of water. It does not follow, however, that the unconsolidated sediments are water bearing in every locality or horizon, for they may either have been drained of their water or they may consist of fine-grained material which does not yield water freely.

Stream deposits.—Where a torrential stream emerges from the mountains its gradient is usually so much diminished that its carrying power is greatly reduced. As a result of this reduction the coarse material that the stream has carried in suspension or has rolled along its bottom is deposited, and only the fine-grained material is ordinarily carried far out into the valley. Hence the alluvial slopes adjacent to the mountains are underlain chiefly by coarse material and the areas most distant from the mouths of the canyons largely by clay and fine sand.

If the streams that pour into the valleys were of constant volume the material which they deposit would be uniformly sorted, but in fact they fluctuate greatly in volume and consequently in carrying power. A stream resulting from a cloud-burst may have such velocity that it will carry large bowlders far into the valley, and a stream resulting from a gentle rain may be so sluggish and may sink so soon after emerging from the mountains that it deposits even the fine-grained material on the upper part of the alluvial slope. Hence the stream deposits in any given locality differ greatly in fineness, and a well sunk into them generally encounters recurring beds of clay, sand, and gravel.

As the streams issuing from the mountains begin depositing immediately upon entering the valley, they soon build up their stream channels above the adjacent parts of the slope. They then break over and find a new course on a lower portion of the slope. This process is repeated many times, the stream swinging from one side of the alluvial fan to the other. Hence the beds of gravel and sand have little lateral continuity, and wells sunk not far apart may have entirely different sections.

The stream deposits are largely composed of clay, sand, gravel, and bowlders and are generally capable of transmitting more or less water. The average size of the constituent particles of the beds and the quantity of water which they will hold decrease with the distance from their source. Wells sunk in the central parts of the valleys may yield smaller quantities of water than those farther up the alluvial slope on account of the greater fineness of the containing beds. On the other hand, on the higher portions of the alluvial slopes the porous beds are likely to be drained of their water, and wells sunk in these places may strike bedrock before they reach the water table.

Lake deposits.—Where a stream empties into a lake its velocity is checked and all the heavier particles it carries are deposited, but the flocculent clayey or sandy material is held in suspension until it has become widely disseminated through the quiet water, and finally it settles evenly over the bottom of the lake. Lake deposits are therefore likely to consist largely of beds of clay and fine-grained sand that will yield only meager supplies of water. No wells have been sunk into known lake beds in this area.

WATER LEVELS.

The water table is the surface below which the pores and crevices of the earth are saturated. The topography of the water table underlying the débris-filled valleys conforms in general to the topography of the surface of the land, but its slopes are more gentle. The water table rises in the direction of the mouths of the canyons, whence

come the principal supplies of water, but the surface rises much more rapidly. Hence, even though in the central part of a valley the water table is near the surface it generally becomes gradually deeper in the direction of the mountains. This increase in the altitude of the surface with respect to the altitude of the water table should be taken into account when a well is sunk on the alluvial slopes.

Springs and alkali flats in the lower parts of a valley indicate that the water table is at the surface in these low places and that it therefore probably extends beneath the entire débris-filled part of the valley. In valleys like Duck and Railroad, in which there are springs and alkali flats, the chances of obtaining water, even on the alluvial slopes, are much better than in valleys that have no such indications of ground water. In prospecting for water on the slopes preference should be given to the side of the valley on which the highest mountains are found, as the water comes most largely from rains in these mountains.

In a dry valley which has no springs nor alkali tracts the chances of obtaining water beneath the alluvial slopes are uncertain. The absence of springs and of alkali shows that the sediments are not saturated to the level of the lowest part of the valley but leaves no clue as to whether the deeper sediments contain water or are entirely dry. If a valley is relatively low or if its sediments are inclosed and underlain by impervious rocks it may contain some water, but if it is high relative to the surrounding region and if the inclosing rocks are faulted or fissured or consist of soluble rocks, such as limestone, its sediments may be entirely dry. Explorations for water in dry valleys should be confined to the lower parts of the slopes and to the localities where the largest canyons discharge their storm waters.

ARTESIAN CONDITIONS.

PREREQUISITE FEATURES OF AN ARTESIAN SYSTEM.

The geologic conditions that are essential to an artesian system are few and simple:[1]

1. An inclined porous stratum, or water-bearing bed, such as coarse sand or gravel, which receives water in its higher portions and transmits it freely to its lower portions.

2. Relatively impervious strata, such as clay or shale, above the water-bearing bed, to confine the water in the lower areas.

3. Resistance to lateral escape of the water from the lower part of the water-bearing bed greater than the resistance to the ascent of the water in the wells. This may be due to either of several factors, among the commonest of which are:

[1] Chamberlin, T. C., Requisite and qualifying conditions of artesian wells: U. S. Geol. Survey Fifth Ann. Rept., pp. 134-135, 1885. Fuller, M. L., Controlling factors of artesian flows: U. S. Geol. Survey Bull. 319, 1908.

(*a*) A bend in the beds, causing the water-bearing stratum to outcrop in another elevated locality, as on the opposite side of the basin.

(*b*) The discontinuance of the water-bearing bed in the lower part of the basin.

(*c*) Loss of porosity in the water-bearing bed.

(*d*) Frictional resistance to lateral movement within the water-bearing bed.

The annual increment must be at least equal to the annual escape from the valley. Few structural valleys are completely closed, most of them having an outlet somewhere, so that more or less water is constantly escaping. In Las Vegas Valley, for example, considerable water flows beneath the surface of the channel of Las Vegas Wash.

SOURCE OF ARTESIAN WATER.

The source of supply of the water of an artesian basin such as Las Vegas Valley is undoubtedly the mountain streams that flow down the alluvial slopes that border it. Most of these streams disappear soon after they reach the slopes, particularly the streams in southeastern Nevada, where none but the flood waters from heavy rains reach the central parts of the valleys. After sinking into the ground the water from these streams percolates downward through the loose material bordering the mountains. If it passes beneath an impervious stratum and becomes confined there, it accumulates and produces an artesian head.

PERMANENCY OF ARTESIAN SUPPLY.

To be permanently successful, an artesian basin should not be drawn upon at a rate in excess of the rate of increment. Many persons believe that artesian supplies are limitless and allow the water from artesian wells to flow continuously without any regard for the future, but the discharge of wells in an artesian basin usually diminishes or ceases entirely after a few years' use. This decrease may be due to the draining of the reservoir, either by intentionally allowing the water to run continuously or by unintentionally allowing it to escape around the outside of the casing of wells. The former waste can be remedied by shutting the water off at the mouth of the well, but the latter, which is due to faulty construction of the well, can be prevented only by proper precautions in drilling.

SPRINGS.

STRUCTURAL SPRINGS.

The rocks exposed in the mountains, which are mainly limestones, quartzites, and igneous material, are relatively impervious. They have, however, been greatly faulted and contain many fissures,

through which the water that falls upon the mountainous areas may descend to great depths. Some large fissures apparently occur along fault planes, and through these the water is returned to the surface and issues in the form of springs. Springs of this type, which may be designated structural springs, generally have large discharges that are comparatively uniform throughout the year. Such springs are found in White River, Pahranagat, and Muddy valleys, where they contribute the principal supplies.

SPRINGS FROM UNCONSOLIDATED SEDIMENTS.

It has been pointed out (p. 22) that in some of the valleys the sediments are saturated with water to the level of the lowest parts of the surface. This is particularly true of Railroad and Duck valleys, which contain considerable alkali and swampy areas. Where this condition obtains, overflow occurs in the low places. A large part of the overflow takes place through minute pores in the soil, from which the water is evaporated so rapidly that its presence would be unnoticed were it not for the accumulation of alkali it leaves upon the surface. Some of the overflow, however, issues as definite streams from large openings in the form of springs or seeps. Springs of this character are generally not of very great value. They usually issue on land that contains too much alkali and is too swampy to be of use except for pasture and hay. They are significant, however, for they show that the sediments contain water.

Springs occur also where a water-bearing stratum among the unconsolidated sediments has been cut by erosion. Several of this type occur in Las Vegas Valley.

SPRINGS FROM IGNEOUS MATERIAL.

Most of the igneous rocks of southeastern Nevada are impervious to water except in cracks and fissures, along which water may percolate with freedom. A considerable amount of volcanic tuff, however, is associated with the lava of the region, and in some places this gives rise to small springs. Seaman, White Rock, and Pahroc springs issue from such material and are all very small.

POOL SPRINGS.

There is an important group of pool springs in Duck Valley near Geyser, where 63 springs occur on a quarter section of land. Most of these springs are deep, jug-shaped reservoirs, which are always partly and sometimes completely covered by a shelf of soil and grass roots. Their depth is not known, but according to popular belief it is very great. In attempting to drink from them many horses and cattle have lost their footing and have sunk beneath the shelf, never to be recovered.

Springs of this type were studied by Meinzer,[1] who offers the following explanation of them:

> That these springs are not merely the return to the surface of water that percolates into the sediments of the adjacent alluvial slopes seems to be shown by the following facts: First, the yield from many of them is larger than would be expected if they were supplied from local sources; second, their yield is nearly uniform, though that of ordinary valley springs fluctuates with the season; third, their location differs from that of ordinary valley springs * * *; fourth, the temperature of many of them is distinctly higher than the mean annual temperature of the region, which is not the case with springs fed from local and shallow sources. All these differences suggest a relation to the rock structure.

KNOLL SPRINGS.

At Tule Springs and Corn Creek Springs in Las Vegas Valley, and at Mesquite Springs in Indian Spring Valley there are knoll springs, consisting of mounds or knolls, averaging about 10 feet in height, from the sides or top of which water flows. The knolls or mounds have probably been built up by dust and sand carried by the wind into the vegetation surrounding the springs, and held there by the moisture. Ordinarily the accumulation continues until it becomes high enough to stop the flow of the spring. Many of the knolls are now dry at the surface, having been closed by the sand and dust, but that they were once springs is proved by the fact that water is found beneath them at shallow depths when they are opened by digging.

HOT SPRINGS.

The temperature of the ground near the surface of the earth fluctuates with the seasonal changes in the weather, but at a short distance below the surface no such fluctuations take place, a constant temperature, which is about the annual mean temperature of the region, being maintained. In openings made in the earth, such as mining shafts and deep wells, the temperature of the rocks increases about 1° F. for each 50 to 100 feet in depth. It is therefore reasonable to assume that at certain depths below the surface the rocks of the earth are at a very high temperature. The temperature of ground water depends on the depth at which it lies below the surface. Water that is returned to the surface from moderate depths has about the mean annual temperature of the region in which it occurs, but water that is returned from greater depths has a higher temperature. Water that penetrates deeply along joints or porous strata gradually becomes greatly heated, and when it is returned to the surface along a fault plane or other fissure it forms a hot spring.

[1] Meinzer, O. E., Ground water in Juab, Millard, and Iron counties, Utah: U. S. Geol. Survey Water-Supply Paper 277, pp. 44–45, 1911.

In places the rocks beneath the surface have been subjected to dynamic action, such as that which causes faulting, folding, and the injection of intrusive and extrusive lavas, all of which are accompanied by heat. Where these phenomena have been in progress the downward increase in heat may be rapid, and the water that issues as hot springs may not come from a very great depth.

Southeastern Nevada contains a number of springs whose waters are warmer than normal. The principal ones are at Lund, Preston, Sunnyside, Hot Creek ranch, Hiko, Alamo, Moapa, Geyser, and Las Vegas. These springs are usually located near fault planes, but the pool springs at Geyser and the large spring near Las Vegas issue from unconsolidated sediments. The rocks of the region have been greatly faulted and folded and intruded by lava and no doubt contain fissures that extend to considerable depths. Water circulating through these is heated by the normal heat of the earth and probably also by the heat generated by the deformation and by volcanic activity.

PERIODIC SPRING.

A spring of an unusual type occurs about 3 miles west of Geyser post office. This spring, which issues from the unconsolidated sediments along a small cliff, probably a recent fault scarp, several miles from the edge of the mountains, has a periodic or geyser action. Normally its discharge is about 1 second-foot, but about every two hours its discharge is doubled or trebled. The temperature of the water is only 54° F., and the fluctuation can therefore not be due to heat, as in geysers.

QUALITY OF WATER.

SUBSTANCES GENERALLY DISSOLVED IN WATER.

Rain and snow contain little mineral matter except small amounts of certain gases and dust. Water percolating through the soil, however, dissolves part of the salts with which it comes in contact, and hence it always contains some mineral matter. The substances which ground waters most commonly carry thus are silica, iron, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulphate, nitrate, and chlorine. While these substances are in solution they are invisible, and unless present in comparatively large quantities they are imperceptible to the taste. When the water is evaporated, however, whether by cooking or directly from the surface of the soil, its mineral matter is left as an incrustation. The large alkali deserts in some parts of the West have been formed by this process, as have also the harmful quantities of alkali deposited on some irrigated fields.

WATER FOR USE IN BOILERS.

The chief troubles in steam boilers arising from the use of waters containing mineral constituents are corrosion, foaming, and the formation of scale. Calcium and magnesium compounds are the chief scale-forming ingredients, and sodium and potassium compounds the chief foaming ingredients. Corrosion is due to the action of acids on the iron of the boiler. Dole,[1] in discussing the classification of water for boiler use, says that the scale and sludge include practically all the suspended matter; the silica, probably precipitated as SiO_2; the iron and aluminum, appearing in the scale as oxide or hydrated oxide; the calcium, precipitated principally in the form of carbonate and sulphate; and the magnesium, found in the deposits principally as the oxide but partly as the carbonate. Their amount is most satisfactorily estimated from field tests by adding the total hardness, the turbidity, and an arbitrary amount for silica. The estimate should be expressed only to the nearest 10 parts and with but two significant figures.

Dole suggests that waters be classified in respect to scale-forming ingredients as follows:

Classification of waters according to scale-forming constituents.[2]

[Parts per million.]

Less than 90	Good.
90 to 200	Fair.
200 to 430	Poor.
430 to 680	Bad.
More than 680	Very bad.

The principal cause of foaming in boilers is an excess of dissolved substances, which increases the surface tension of the liquid, thereby reducing the readiness with which the steam bubbles can break. As alkali salts remain dissolved in the boiler water while the greater portion of the other substances is precipitated, the foaming tendency is commonly measured by the degree of concentration of the alkali salts in solution. Stabler suggests that 2.7 times the estimated total of the alkali bases represents with sufficient accuracy the probable amount of the foaming ingredients.

Classification of waters according to foaming constituents.[3]

[Parts per million.]

Less than 70	Very good.
70 to 150	Good.
150 to 250	Fair.
250 to 400	Bad.
More than 400	Very bad.

[1] Dole, R. B., Rapid examination of water: Econ. Geology, vol. 6, No. 4, pp. 353–356, 1911.

[2] Am. Ry. Eng. and Maintenance of Way Assoc. Proc., vol. 5, p. 595, 1904.

[3] Idem, vol. 9, p. 134, 1908.

Corrosion, or "pitting," according to Dole, is caused chiefly by the solvent action of acids on the iron of the boiler. Aside from free acids, which are rarely encountered in natural waters, acids liberated by deposition of magnesium as the hydrate are commonly believed to be the important cause of corrosion. It is believed that such radicles may pass into equilibrium with other bases in solution, displacing equivalent proportions of carbonate and bicarbonate, or they may decompose carbonates that have been precipitated as scale, or they may combine with the iron of the boiler. The certainty of these reactions is not known and can be expressed only as a probability, even after the most complete analysis. If the acids liberated by the deposition of magnesium exceed the amount required to decompose all the carbonate and bicarbonate, corrosion is likely to occur; and if they equal or are less than that amount, corrosion is not likely to occur. Intermediate conditions are uncertain. Formulas for expressing these relations have been adapted by Dole from Stabler's scheme:[1]

If $0.033CO_3+0.016HCO_3$ equals or exceeds $0.082Mg$, no corrosion is likely to occur.

If $0.033CO_3+0.016HCO_3$ is less than $0.082Mg$, corrosion is likely to occur.

In these formulas CO_3, HCO_3, and Mg represent respectively carbonate, bicarbonate, and magnesium, determined by analysis.

WATER FOR DOMESTIC USE.

The amount of dissolved substances permissible in water for domestic use depends largely on their nature. Poisonous substances, such as arsenic, copper, lead, zinc, and barium, should not be present, and iron is permissible only in small amounts. Calcium and magnesium in moderate amounts produce no harmful effects on persons using water containing them, but in large amounts they are very troublesome in waters used in the lavatory or laundry. They cause hardness in water, and their amount is indicated by the quantity of soap required to create a lather.

The most troublesome mineral substances in ground water used for domestic purposes are the alkali carbonates. Water containing about 200 parts per million of these minerals may be drunk without harm, but water containing 300 or more parts should be avoided by most persons.

About 400 parts per million of sulphate is perceptible to the taste, and water containing as much as 1,500 parts, though potable, is not refreshing and would be objectionable to most persons on account of the laxative effect of the sulphate. It is also useless for cooking.

[1] Stabler, Herman, Some stream waters of western United States: U. S. Geol. Survey Water-Supply Paper 274, p. 175, 1911.

The chloride radicle is perceptible to the taste when 250 parts per million is present, but water containing much greater amounts can be drunk. The objection to a high content of chlorine in drinking water is due to the fact that it increases instead of quenching thirst.

The large amounts of carbonate, sulphate, and chlorine contained in water that may be used in an emergency afford no safe criteria for judging the fitness of a water for domestic supply.

WATER FOR IRRIGATION.

It has been pointed out that all natural water contains mineral substances in solution and that these substances are chiefly calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulphate, and chloride. Certain amounts of these radicles are indispensable to the proper growth and development of plants, but excessive amounts are inimical to their existence. Many soils contain as much of them as is necessary for ordinary crops. When irrigation waters are evaporated from the fields the quantity of salts in the soil is augmented by the amount held in solution by the water, and the continued evaporation of such water may in time ruin the land for farming.

The salts most injurious to cultivated crops are those of sodium and potassium, commonly known as the alkalies. The usual chemical practice is to determine the sodium and potassium together and to regard them as sodium, so that the alkali compounds are reported as carbonate, bicarbonate, sulphate, and chloride of sodium. All these are not equally toxic to vegetation. Thorough experiments conducted in California by Hilgard, Loughridge, and others show that the carbonates are the most injurious and the sulphates are the least injurious to plants, the chlorides holding an intermediate position. Basing his computations on the data gathered by Hilgard and others, Stabler[1] found the relative harmfulness of the alkalies to cultures to be, sodium as Na_2CO_3, 10; sodium as NaCl, 5; sodium as Na_2SO_4, 1. That is, assuming the toxicity of sodium as Na_2SO_4 to be 1, the toxicity of sodium as NaCl would be 5, and the toxicity of sodium as Na_2CO_3 would be 10.

Stabler[1] has deduced formulas for computing, from the results of a chemical analysis, or field assay, an alkali index, or "alkali coefficient," by which waters may be classified according to their value for irrigation. He says:

> The alkali coefficient is a purely arbitrary quantity intended solely to facilitate the comparison of waters to be used for irrigation. It may be defined as the depth in inches of water which on evaporation would yield sufficient alkali to render a

[1] Stabler, Herman, op. cit., pp. 177–179.

4-foot depth of soil injurious to the most sensitive plants. Thus if the alkali coefficient of a water is found to be 17, 17 inches in depth of that water contains sufficient alkali to render injurious to sensitive crops the soil on which it is applied. Whether injury would actually result from the application of such a water to any particular piece of land, however, depends on methods of irrigation, the crops grown, the character of the soil, and drainage conditions, and it should be clearly understood that the alkali coefficient in no way takes account of such conditions.

In the following formulas for computing the alkali coefficient (k) of a water Na, Cl, and SO_4 represent, respectively, the quantities, in parts per million, of sodium, chloride, and sulphate, as determined by analysis:

If $Na-0.65Cl$ is zero or negative, $k=\frac{2040}{Cl}$

If $Na-0.65Cl$ is positive, but not greater than $0.48SO_4$, $k=\frac{6620}{Na+2.6Cl}$

If $Na-0.65Cl-0.48SO_4$ is positive, $k=\frac{662}{Na-0.32Cl-0.43SO_4}$

If sodium has not been determined, as in a field assay, it may be computed by the following formula:

$$Na=0.83CO_3+0.41HCO_3+0.71Cl+0.52SO_4-0.5\text{ hardness.}$$

The following classification, proposed by Stabler,[1] may be used to interpret the calculated alkali coefficients:

Classification of water for irrigation by content of alkali.

Alkali coefficient (k):	
Greater than 18	Good.
6 to 18	Fair.
1.2 to 6	Poor.
Less than 1.2	Bad.

ANALYSES.

Forty-two samples of water were analyzed for the Geological Survey, in connection with the present investigation, by Dr. S. C. Dinsmore. Tests were made for silica, iron, calcium, magnesium, and for the carbonate, bicarbonate, sulphate, nitrate, and chloride radicles. In five of the analyses the amounts of sodium and potassium were determined, but in the others they were computed. The total hardness, scaling, and foaming ingredients, probability of corrosion, and alkali coefficient have been calculated by the writer.

[1] Op. cit., p. 179.

No.	Total hardness as $CaCO_3$.	Total solids.	Estimated scale-forming ingredients.	Estimated foaming ingredients.	Probability of corrosion.[a]	Quality for boiler use.	Quality for domestic use.	Alkali coefficient (k).	Quality for irrigation.	Mineral content.	Chemical character.
1	141	251	170	120	N. C.	Fair	Good	35	Good	Moderate	Ca-CO_3.
2	243	258	270	70	(?)	Poor	...do	35	...do	...do	Do.
3	672	1,044	790	130	C.	Very bad	Poor	30	...do	High	Ca-SO_4.
4	782	1,380	890	280	C.	...do	...do	15	Fair	...do	Do.
5	528	713	610	50	C.	Bad	...do	110	Good.	...do	Do.
6	340	430	400	30	(?)	Poor	Good.	18	...do	Moderate	Do.
7	592	857	690	40	C.	Very bad	Poor	60	...do	High	Do.
8	300	545	410	90	(?)	Poor	Good	100	...do	...do	Ca-CO_3.
9	,410	2,827	1,600	800	C.	Very bad	Poor	4.8	Poor	Very high.	Ca-SO_4.
10	456	617	520	30	C.	Bad	Fair	135	Good	High	Do.
11	234	267	270	45	(?)	Poor	Good	300	...do	Moderate	Ca-CO_3.
12	237	318	270	30	(?)	...do	...do	185	...do	...do	Do.
13	343	455	400	60	(?)	...do	...do	95	...do	...do	Ca-SO_4.
14	431	563	500	125	(?)	Bad	...do	90	...do	High	Do.
15	,220	2,012	1,400	270	C.	Very bad	Poor	12	Fair	...do	Do.
16	250	287	290	45	(?)	Poor	Good	140	Good	Moderate	Ca-CO_3.
17	,865	7,355	2,100	4,100	C.	Very bad	Unfit	2.1	Poor	Very high.	Na-SO_4.
18	241	835	310	495	(?)	Poor	Fair	16	Fair	High	Do.
19	750	3,815	890	2,400	C.	Very bad	Bad	3.9	Poor	Very high.	Do.
20	,690	3,266	1,910	590	C.	...do	...do	5.6	...do	...do	Ca-SO_4.
21	208	218	250	80	(?)	Poor	Good	26	Good	Moderate	Ca-CO_3.
22	338	324	370	85	(?)	...do	...do	30	...do	...do	Do.
23	194	283	260	5	(?)	...do	...do	115	...do	...do	Do.
24	244	255	290	95	(?)	...do	...do	26	...do	...do	Do.
25	263	340	320	35	(?)	...do	...do	170	...do	...do	Do.
26	228	315	290	60	(?)	...do	...do	130	...do	...do	Do.
27	227	306	280	50	(?)	...do	Good	140	...do	...do	Ca-CO_3.
28	176	303	230	160	N. C.	...do	...do	75	...do	...do	Do.
29	310	587	370	190	N. C.	...do	Fair	50	...do	High	Do.
30	615	3,023	650	2,200	N. C.	Bad	Bad	2.5	Poor	Very high.	Na-SO_4
31	356	590	425	180	(?)	Poor	Fair	50	Good	High	Ca-CO_3.
32	100	421	200	180	N. C.	Fair	Good	13	Fair	Moderate	Na-CO_3.
33	300	465	350	80	N. C.	Poor	...do	55	Good	...do	Ca-CO_3.
34	303	609	350	140	N. C.	...do	Fair	23	...do	High	Do.
35	299	272	340	30	(?)	...do	Good	155	...do	Moderate	Do.
36	247	263	290	0	(?)	...do	...do	1,000	...do	...do	Do.
37	213	233	250	860	(?)	...do	...do	315	...do	...do	Na-CO_3.
38	181	330	220	80	N. C.	...do	...do	40	...do	...do	Ca-CO_3.
39	325	509	410	100	(?)	...do	Poor	19	...do	...do	Do.
40	495	940	570	270	C.	Bad	Fair	13	Fair	High	Ca-SO_4.
41	,127	3,053	1,280	1,300	C.	...do	Poor	1.4	Poor	Very high.	Na-SO_4.
42	262	132	300	0	C.	Fair	Good	930	Good	Low	Ca-CO_3.

—n. Rept. State engineer Nevada, p. 249, 1913).

Analyses and classification of water from southeastern Nevada.

[Parts per million. Analyst, S. C. Dinsmore, Agricultural Experiment Station, Reno, Nev.]

No.	Owner.	Location.	Date of collection.	Source.	Depth of well.	Depth to water level.	Diameter.	Depth of casing.	Yield.	Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total hardness as $CaCO_3$.	Total solids.	Estimated scale-forming ingredients.	Estimated foaming ingredients.	Probability of corrosion.[a]	Quality for boiler use.	Quality for domestic use.	Alkali coefficient (k).	Quality for irrigation.	Mineral content.	Chemical character.
					Feet.	*Feet.*		*Feet.*	*Sec.-ft.*																					
1	F. W. Eglington	NW. ¼ sec. 24, T. 20 S., R. 60 E.	Sept. 14, 1912	Well	232	Artesian.	8 inches	154	1.37	7	0.02	52	2.6	43	0.0	235	34	1.3	4.0	141	251	170	120	N. C.	Fair	Good	35	Good	Moderate	$Ca-CO_3$.
2	W. S. Park	NW. ¼ sec. 22, T. 20 S., R. 61 E.	Sept. 16, 1912	Spring					.90	8	.01	53	27	26	.0	251	33	2	55	243	258	270	70	(?)	Poor	...do	35	...do	...do	Do.
3	Clark & Ronnow	NW. ¼ sec. 1, T. 22 S., R. 61 E.	Sept. 17, 1912	Well	412	Artesian.	12 inches		.71	35	.05	177	56	47	.0	215	483	1	67	672	1,014	790	130	C.	Very bad	Poor	30	...do	High	$Ca-SO_4$.
4	J. F. Miller	...do	...do	...do	100	Artesian.	6 inches		.67	36	.02	193	73	104	.0	191	587	4	168	782	1,380	890	280	C.	...do	...do	15	Fair	...do	Do.
5	Carey Act, list 10	Sec. 34, T. 21 S., R. 61 E.	Sept. 18, 1912	...do					.09	21	.02	134	47	18	.0	207	358	1.5	17	528	713	610	50	C.	Bad	...do	110	Good.	...do	Do.
6	R. O. Barnsley	SW. ¼ sec. 27, T. 21 S., R. 61 E.	...do	...do	400	Artesian.	8 inches		.09	21	.02	85	31	10	.0	210	165	4	10	340	430	400	30	(?)	Poor	Good.	18	...do	Moderate	Do.
7	E. A. Wixen	NW. ¼ sec. 10, T. 22 S., R. 61 E.	...do	...do	246	Artesian.	12 inches		1.18	30	.02	155	50	15	.0	205	405	.0	35	592	857	690	40	C.	Very bad	Poor	60	...do	High	Do.
8	Clark County Land Co	NW. ¼ sec. 3, T. 21 S., R. 62 E.	Sept. 20, 1912	...do	30	30	10 inches			83	.02	58	38	31	.0	251	110	.5	11	300	545	410	90	(?)	Poor	Good	100	...do	...do	$Ca-CO_3$.
9	A. D. Bishop	Sec. 28, T. 21 S., R. 62 E.	...do	...do	18		5 feet			71	1	295	164	297	12	197	1,233	.5	417	1,410	2,827	1,600	800	C.	Very bad	Poor	4.8	Poor	Very high	$Ca-SO_4$.
10	B. R. Jefferson	SE. ¼ sec. 30, T. 21 S., R. 62 E.	Sept. 21, 1912	...do	405	Artesian.	3 inches	148	.08	14	.15	102	49	10	.0	204	278	.75	15	456	617	520	30	C.	Bad	Fair	135	Good	High	Do.
11	Las Vegas	Sec. 30, T. 20 S., R. 61 E.	Sept. 23, 1912	Las Vegas Spring.					5.74	13	Trace.	56	23	[b] 17	.0	239	43	6	2.0	234	267	270	45	(?)	Poor	Good	300	...do	Moderate	$Ca-CO_3$.
12	Las Vegas Syndicate	NE. ¼ sec. 3, T. 21 S., R. 61 E.	...do	Well	442	Artesian.	8 inches	400		8	.08	54	25	10	.0	251	39	.0	10	237	318	270	30	(?)	...do	...do	185	...do	...do	Do.
13	Frank Cliff	Sec. 27, T. 20 S., R. 61 E.	...do	...do	28	12	4 feet			33	1.5	60	47	23	.0	273	141	Trace.	18	343	455	400	60	(?)	...do	...do	95	...do	...do	$Ca-SO_4$.
14	Arden Plaster Co	Arden	Sept. 18, 1912	Cottonwood Spring.						19	.4	102	43	[c] 46	.0	290	146	.45	11	431	563	500	125	(?)	Bad	...do	90	...do	High	Do.
15		Sec. 28, T. 21 S., R. 62 E.	Dec. 24, 1912	Grapevine Spring.						55	.3	275	130	99	.0	239	959	.3	172	1,220	2,012	1,400	270	C.	Very bad	Poor	12	Fair	...do	Do.
16		Sec. 27, T. 17 S., R. 59 E.	Dec. 8, 1912	Corn Creek Spring.					.2	18	.03	54	28	17	.0	292	26	4	12	250	287	290	45	(?)	Poor	Good	140	Good	Moderate	$Ca-CO_3$.
17	Clark County Land Co	NW. ¼ sec. 5, T. 21 S., R. 62 E.	Dec. 24, 1912	Well	546	13	8 inches			15	.02	500	150	1,509	Trace.	51	4,008	.0	658	1,865	7,355	2,100	4,100	C.	Very bad	Unfit	2.1	Poor	Very high	$Na-SO_4$.
18	Muddy Valley Irrigation Co	Narrows below Moapa	Oct. 1, 1912	Muddy River					([d])	32	.7	91	3.3	183	.0	245	304	1	86	241	835	310	495	(?)	Poor	Fair	16	Fair	High	Do.
19	San Pedro, Los Angeles & Salt Lake R. R. Co.	St. Thomas	Sept. 30, 1912	Well	461	284	11⅝ inches	460	.13	17	.9	159	86	891	.0	131	2,079	.0	295	750	3,815	890	2,400	C.	Very bad	Bad	3.9	Poor	Very high	Do.
20	Levi Syphus		Sept. 28, 1912	Spring						24	.6	428	151	220	.0	159	1,638	1	331	1,690	3,266	1,910	590	C.	...do	...do	5.6	...do	...do	$Ca-SO_4$.
21	J. F. Wambolt		Oct. 14, 1912	Pool spring					1	18	.7	52	19	30	.0	218	8.6	.0	5.0	208	218	250	80	(?)	Poor	Good	26	Good	Moderate	$Ca-CO_3$.
22	Pioche Waterworks Co		Oct. 17, 1912	Spring						13	.02	74	33	[e] 31	.0	263	16	3	5.0	338	324	370	85	(?)	...do	...do	30	...do	...do	Do.
23		Panaca	Oct. 5, 1912	Warm spring						46	.3	40	23	2.1	.0	178	27	.0	18	194	283	260	5	(?)	...do	...do	115	...do	...do	Do.
24	Lund Irrigation Co	Lund	Oct. 26, 1912	Cold spring					[f] 5.36	16	.6	60	23	35	4.8	258	20	4	4.0	244	255	290	95	(?)	...do	...do	26	...do	...do	Do.
25	Adams & McGill	Sec. 18, T. 6 N., R. 61 E.	...do	Hot spring						24	.2	66	24	13	.0	278	48	.4	10	263	340	320	35	(?)	...do	...do	170	...do	...do	Do.
26		Hiko	Nov. 15, 1912	Spring					[g] 9	35	.0	52	24	22	.0	272	36	.8	11	228	315	290	60	(?)	...do	...do	130	...do	...do	Do.
27		Sec. 10, T. 5 S., R. 60 E.	Nov. 16, 1912	Crystal Spring.					7	26	.02	53	23	19	.0	261	37	.75	11	227	306	280	50	(?)	...do	Good	140	...do	...do	$Ca-CO_3$.
28		Sec. 36, T. 5 S., R. 60 E.	...do	Ash Spring					[g] 20	34	.16	49	13	[h] 59	.0	259	46	.4	11	176	303	230	160	N. C.	...do	...do	75	...do	...do	Do.
29		Alamo	Nov. 20, 1912	Irrigation ditch.						32	.0	68	34	70	.0	434	72	.4	22	310	587	370	190	N. C.	...do	Fair	50	...do	High	Do.
30			Nov. 21, 1912	Pahranagat Lake.						22	.02	18	139	813	141	802	1,086	.0	254	615	3,023	650	2,200	N. C.	Bad	Bad	2.5	Poor	Very high	$Na-SO_4$.
31	Irwin's ranch	Railroad Valley	Oct. 29, 1912	Duckwater Creek.					([i])	36	.1	72	43	69	.0	414	127	1.6	25	356	590	425	180	(?)	Poor	Fair	50	Good	High	$Ca-CO_3$.
32	Railroad Valley Saline Co	...do	Oct. 31, 1912	Potash well	1,204	Artesian.	12 inches			83	1.7	26	8.9	69	.0	223	5.7	3.0	45	100	421	200	180	N. C.	Fair	Good	13	Fair	Moderate	$Na-CO_3$.
33		...do	...do	Blue Eagle Spring.						17	.6	80	24	30	.0	385	34	.0	10	300	465	350	80	N. C.	Poor	...do	55	Good	...do	$Ca-CO_3$.
34	Al. Sandy	Indian Spring	Dec. 14, 1912	Well	40	37	6 feet			14	.01	67	33	52	.0	427	40	.0	18	303	609	350	140	N. C.	...do	Fair	23	...do	High	Do.
35	Ira MacFarland	...do	...do	...do		11.4	6 inches			15	.0	59	37	11	.0	334	41	.0	6	299	272	340	30	(?)	...do	Good	155	...do	Moderate	Do.
36	...do	...do	...do	...do	18	16	6 feet			17	.0	56	26	Trace.	.0	269	19	.5	2.0	247	263	290	0	(?)	...do	...do	1,000	...do	...do	Do.
37	...do	...do	Dec. 10, 1912	...do		70	8 inches			20	.2	46	24	312	.0	230	22	.0	6.5	213	233	250	860	(?)	...do	...do	315	...do	...do	$Na-CO_3$.
38	Las Vegas & Tonopah R. R. Co.	...do	Dec. 15, 1912	Indian Spring.					.91	17	.16	48	15	[j] 31	.0	239	28	.0	5.0	181	330	220	80	N. C.	...do	...do	40	...do	...do	$Ca-CO_3$.
39			Oct. 18, 1912	Bristol well	51	43				49	.7	76	33	37	.0	187	71	32	110	325	509	410	100	(?)	...do	Poor	19	...do	...do	Do.
40	San Pedro, Los Angeles & Salt Lake R. R. Co.	Dry Lake	Sept. 24, 1912	Well						22	.5	116	50	100	.0	178	335	.0	155	495	940	570	270	C.	Bad	Fair	13	Fair	High	$Ca-SO_4$.
41	Bryant Whitmore	Sec. 33, T. 16 S., R. 68 E.	Nov. 29, 1912	...do		20	5 feet			55	.2	213	145	480	.0	256	1,360	.0	387	1,127	3,053	1,280	1,300	C.	...do	Poor	1.4	Poor	Very high	$Na-SO_4$.
42	Thompson & Gunnel	Geyser	Oct. 14, 1912	Geyser Spring.						11	.1	44	37	Trace.	.0	124	11	22	2.0	262	132	300	0	C.	Fair	Good	930	Good	Low	$Ca-CO_3$.

[a] N. C., Noncorrosive; C., corrosive; (?), corrosion uncertain.
[b] Na, 11; K, 6.
[c] Na, 36; K, 10.
[d] See table of discharge measurements, p. 61.
[e] Na, 26; K, 5.0.
[f] Measurement by W. M. Kearney, State engineer (Bienn. Rept. State engineer Nevada, p. 249, 1913).
[g] Estimated.
[h] Na, 45; K, 14.
[i] See p. 70.
[j] Na, 21; K, 9.7.

WATER SUPPLY BY AREAS.

LAS VEGAS DRAINAGE BASIN.

LOCATION AND EXTENT.

Las Vegas Valley, which can be reached by the San Pedro, Los Angeles & Salt Lake and the Las Vegas & Tonopah railroads, is a dipper-shaped basin lying in the central part of Clark County, Nev., and comprising about 600 square miles of arable land (Pls. I, in pocket, and II). The name, which is of Spanish origin, meaning "the Meadows," was first used by the Spanish explorers on account of the patches of grass land near the springs in the valley. The axis of the valley, which extends nearly north and south, is about 60 miles long. The broadest part of the valley is in the vicinity of Las Vegas.

TOPOGRAPHY.

Las Vegas Valley occupies a structural trough practically surrounded by mountains, the only exit for surplus waters being through Las Vegas Wash. (See Pl. II.) It is bounded on the east by a practically continuous mountain wall formed by the Las Vegas, Sheep, and Desert ranges, and on the west by the Spring Mountain and the Pintwater ranges. The Spring Mountain Range rises to an imposing altitude, culminating in Charleston Peak at 11,910 feet above sea level. On the south the valley is bounded by mountains to which no names have been applied but which rise 3,000 to 4,000 feet above the valley. On the northeast Las Vegas Pass leads into Dry Lake Valley, and on the northwest a low alluvial divide leads into Indian Spring Valley. Las Vegas Wash, the only outlet for surplus waters, descends to Colorado River from the southeastern part of the valley through a rock canyon.

Lee,[1] who has studied the geology of the western Arizona region, concludes that the gorge of the Grand Canyon of the Colorado was eroded during three periods of downcutting, separated by long periods of nonerosion, all in the Pleistocene epoch.

The erosional features of Las Vegas Valley seem to confirm Lee's theory. Three terraces, indicating three periods of erosion, are prominently developed. Unfortunately the contour interval used in the topographic survey of the Las Vegas quadrangle is too great to show these features, but they are shown by means of hachures on Plate II.

The most prominent terrace lies just east of the town of Las Vegas and bounds the low-lying bottom land in the eastern part of the valley. Several important springs issue from the valley fill along its edge. It is prominently developed at the Kyle (or Park), Stewart,

[1] Lee, W. T., Geologic reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, pp. 62–66, 1908.

and Las Vegas ranches, whence it swings eastward around Ladd's resort, then southward past Indian, Fourmile, Cow, and Grapevine springs, and is again prominently developed about 2 miles east of Mesquite Springs. The terrace at Las Vegas Spring, which is slightly higher than the one east of the town, seems to grade insensibly into it, but it may have been formed at an intermediate period.

The next prominent terrace has its best development at the small spring about 1½ miles west of Las Vegas Spring, but it is also fairly well developed 2½ miles northwest of Eglington's ranch. (See Pl. II.)

The next terrace is well developed at Tule Springs and seems to be present along the north side of the valley to Dike station on the railroad. White clay, which outcrops at its margin, contains the mastodon and fresh-water remains that are mentioned on page 35.

Erosion and deposition have tended to obliterate the terraces, especially the two higher ones, which were not seen except at the places noted.

The northern part of the valley, north of Owens, once contained a lake, which has been drained by the channel leading from the vicinity of Owens to Tule Springs. This lake was probably short lived and carved only slight shore features, which have been obliterated in most places. They are best exposed in the northwest part of the valley, which now contains a playa or "dry" lake. During most of the year the ground is dry, hard, and glistening, but at times it is covered by a few inches of water.

GEOLOGY.

BEDROCK FORMATIONS.

The Las Vegas, Sheep, and Desert ranges are composed of rocks of Cambrian, Ordovician, Silurian, Devonian, and Carboniferous age.[1] The strata, which consist of limestone, gypsum, sandstone, quartzite, and slates, and are very complexly folded and faulted, form, according to Spurr, a northeast-southwest syncline. The Spring Mountain and the Pintwater ranges, which form the western boundary, are composed of rocks of Cambrian, Carboniferous, Jurassic, and Triassic ages. The Paleozoic strata consist of limestone, quartzite, and shale; and the Mesozoic of limestone, gypsum, sandstone, shale, and conglomerate. The rocks in these mountains have been greatly folded and faulted. Sections of Spring Mountain (see fig. 3) adapted from Spurr's report [2] afford a comprehensive idea of the general structure.

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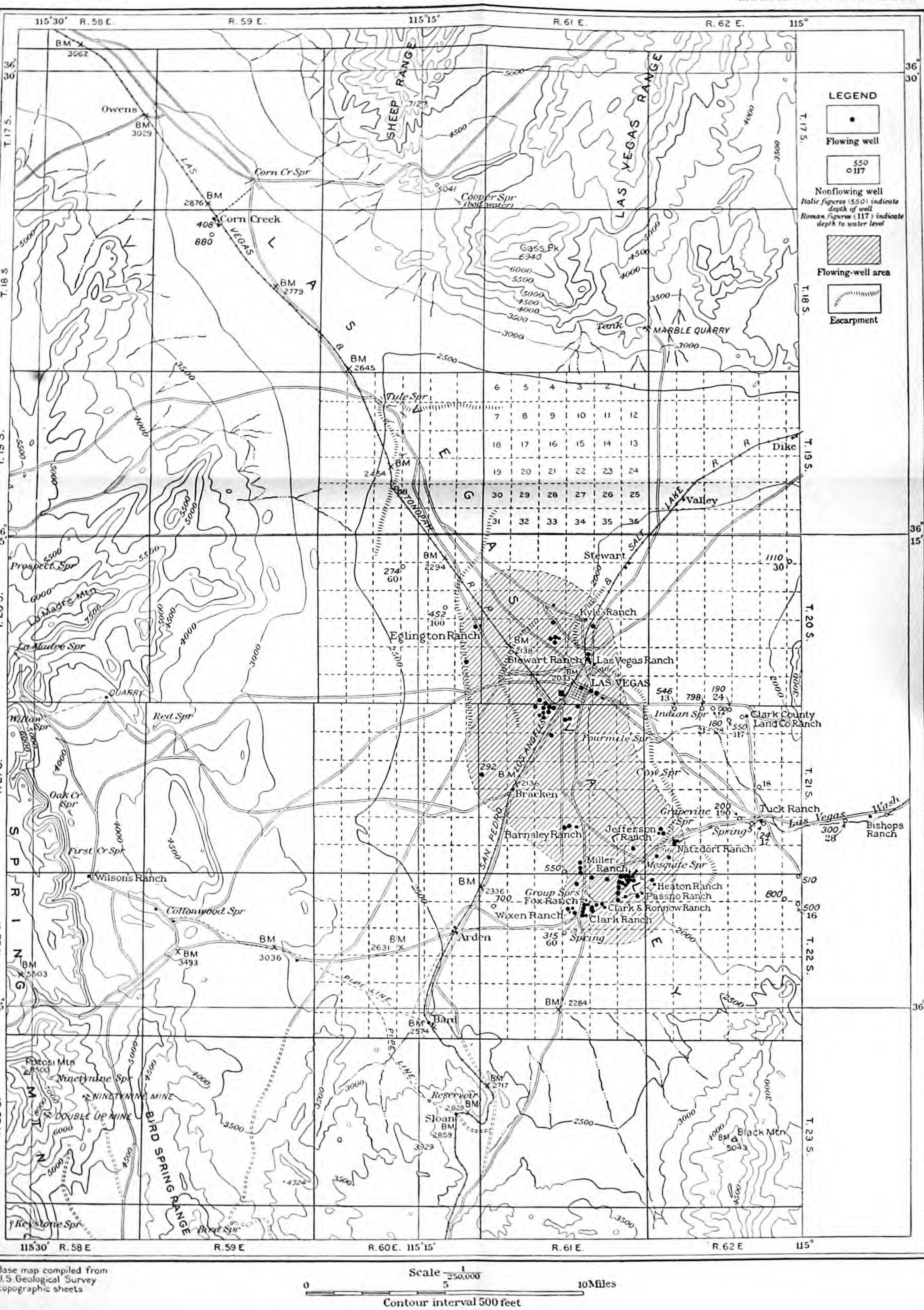
[1] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel: U. S. Geol. Survey Bull. 208, pp. 155–159, 1903.

[2] Idem, fig. 22, p. 176.



Base map compiled from U.S. Geological Survey topographic sheets

Scale $\frac{1}{250,000}$

0 5 10 Miles

Contour interval 500 feet

MAP OF LAS VEGAS VALLEY, NEV.

The mountains on the south are composed principally of limestones, probably of Carboniferous age, which dip to the south.

The terraces above mentioned seem to have been produced by erosion in the Pleistocene epoch. The fresh-water and mastodon remains in the upper and oldest terrace indicate that the unconsolidated sediments were deposited in a closed basin. Deposition was then interrupted during a humid stage and the valley was excavated, leaving the highest terrace as a shelf or platform. This stage of erosion was brought to a close by a climatic change which began an arid stage not unlike the one now prevailing in this region. During this stage the valley was again filled with débris, but not to the level of the oldest terrace. The arid stage of deposition was stopped by a humid stage, during which the valley was again excavated. This process was again repeated and the lowest terrace was formed, since which time the climatic conditions have been more uniformly dry and no erosion has taken place.

These stages of erosion and deposition may have been contemporaneous with glacial and interglacial stages in the northern United States and Canada and also with the fluctuations in the water level in Lake Bonneville and Lake Lahontan in the Great Basin.

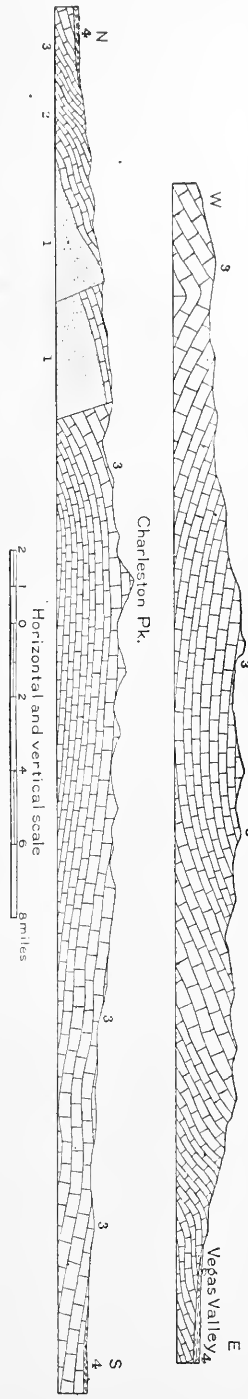


FIGURE 3.—Sections across Spring Mountain. 1, Cambrian quartzites chiefly; 2, heavy limestones, probably Cambrian, Silurian, and Devonian; 3, Carboniferous limestones; 4, Valley wash.

VALLEY FILL.

Character and depth.—The valley has been partly filled with débris washed from the surrounding mountains. These unconsolidated sediments extend to an unknown depth, the deepest well, which goes down about 1,100 feet, apparently ending in valley fill. The following logs of wells, reported by the drillers, show the materials penetrated:

Log of Las Vegas Artesian Water Syndicate well No. 1 (NW. corner of NE. ¼ sec. 21, T. 20 S., R. 61 E.).

	Feet.
Lime	0–28
First water at 28 feet.	
Lime and clay	28–40
Hard cemented lime	40–50
Lime and clay mixed	50–70
Hard cemented lime	70–85
Clay mixed with lime	85–105
Very hard material	105–110
Clay and lime mixed	110–130
Limerock	130–145
Clay and soft lime	145–179
Water at 174 feet flowed.	
Hard streak	179–185
Lime and clay	185–189
Hard rock	189–199
Bottom of 12-inch casing at 194 feet.	
Clay and limerock	199–203
Hard limerock, porous	203–211
Clay with rock	211–213
Bottom of 10-inch casing at 214 feet.	
Hard streak	213–225
Rock	225–230
Sand and pebbles	230–236

Log of Las Vegas Artesian Water Syndicate well No. 3 (NW. ¼ SE. ¼ sec. 21, T. 20 S., R. 61 E.).

	Feet.
Soil	0–12
White clay	12–22
Limerock	22–28
Water.	
White clay (talc)	28–80
Sand and clay	80–85
White clay	85–100
Yellow sand and clay	100–105
White clay	105–108
Red clay and sand	108–115
White clay	115–120
Yellow clay	120–130
White clay	130–135
Yellow clay and sand	135–185
Limerock	185–190
Yellow to red clay	190–230
Sandrock	230–235
Red clay	235–268

The well is cased to 27 feet.

Log of Clark County Land Co.'s well (NW. ¼ sec. 5, T. 21 S., R. 62 E.).

	Feet.
Soil	0–14
Hardpan	14–34
Water at 18 feet.	
Yellow clay	34–50
Streaks of white and yellow clay	50–75
Red sandy clay	75–170
Gray hard clay	170–190
Gray soft clay	190–200
Hard shell	200–202
Softer clay	202–205
Red clay, sandy	205–268
Yellow clay, sticky	268–288
Yellow clay, sandy	288–385
Sandstone	385–390
Yellow clay	390–395
Sand	395–397
Yellow clay	397–400
Sand and water	400–401
Yellow clay, soft and sticky	401–496
Hard shell	496–497
Yellow clay, sticky	497–510
Water	510
Sand, fine	546

Water stands in hole 13 feet below surface.

Age.—The beginning of the deposition of the valley fill in the Las Vegas basin probably dates back to Tertiary time, when the major topography of the general region began to take form. The presence of mastodon remains in several parts of the valley indicates that the valley was receiving deposits in Tertiary time. Spurr,[1] quoting notes collected by R. B. Rowe, says:

From the valley some distance west of Las Vegas mastodon teeth were collected. About midway between Corn Creek and Tule Springs mastodon teeth and bones have been found * * * in a clay bank some 10 or 15 feet high. * * *

The valley between Las Vegas, Tule Springs, and Corn Creek seems to be filled with lake deposits. About Tule Springs, and from there up the valley, are probably the remnants of an old dry lake bed or playa. The deposits do not have the appearance of the Tertiary lake deposits but resemble exactly the clay deposits in the present dry lakes. Underlying these is a gravel or talus deposit.

The presence of fossils of very small fresh-water pelecypods and gastropods in the beds containing the mastodon remains indicates that the débris was deposited in a shallow fresh-water lake.

There are good exposures of the unconsolidated sediments, but with the exception of the mastodon remains mentioned above there are no fossils to give a clüe to the age of the valley fill.

[1] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel: U. S. Geol. Survey Bull. 208, p. 157, 1903.

VEGETATION.

The plants in Las Vegas Valley are largely those found in other dry semitropical parts of the United States. Except where the ground water is near the surface, shadscale and creosote are the dominant types. Where ground water is found at shallow depths, mesquite, willow, greasewood, arrow weed, and quail brush predominate. On the high, dry slopes the giant yucca, Spanish bayonet, prickly pear, and thorn bush are found. In the northern part of the valley a species of saltbush, *Atriplex hymenelytra*, locally known as "desert holly," is found, which is beginning to have commercial value for use in funeral decorations.

SOIL.

The soil in Las Vegas Valley is in most places a sandy loam. On the alluvial slopes and near the mountains considerable quantities of gravel and coarse bowlders lie on the surface. In the low central part of the valley the wind has produced a large number of gypseous sand dunes, which are a serious detriment to agriculture. Over a considerable area in the low part of the valley the soil consists of fine-grained pale gypseous material that has a loose, powdery consistency when dry and is underlain by a dense, clayey subsoil. This soil is of doubtful value for agricultural purposes.

The soil throughout the valley contains considerable gypsum, which can be observed as white flakes or grains that to a person unaccustomed to such phenomena have the appearance of white alkali. In the table on page 37 are given analyses of the water-soluble constituents of seven samples of soil in the valley. These analyses were made by Dr. S. C. Dinsmore, chemist of the Nevada Agricultural Experiment Station. Tests were made for the carbonate (CO_3), bicarbonate (HCO_3), and chloride (Cl) radicles, but not for the sulphate radicle. The chloride and the sulphate form the so-called white alkali and the carbonate forms the black alkali.

The amount of alkali that can be tolerated by plants has been the subject of much investigation by agricultural experts, who have determined fairly definite limits. The amount permissible, however, is dependent on related conditions, such as the climate and content of other salts. Crops can be grown in a higher percentage of alkali in Montana, for instance, than in southern California. Crops can also be grown in a higher percentage of alkali where gypsum forms a large part of the soil than in a soil where gypsum is absent or is present in only small quantities. The highest amounts of alkali in soil in which most ordinary crops can be grown successfully appear to be about as follows: Sodium chloride (NaCl), from 0.25 to 0.50 per cent of the total soil; sodium carbonate (Na_2CO_3), from 0.05 to 0.20 per cent; and sodium sulphate (Na_2SO_4), from 0.50 to 1 per cent. The presence

of gypsum in the Las Vegas Valley has, however, an ameliorating effect on the alkali, and it is possible that crops may be grown there in soil containing even higher percentages of alkali than those given.

Samples Nos. 1, 3, and 5 of the following table were taken from alfalfa fields; Nos. 2, 4, and 6 from gardens; and No. 7 from uncultivated land. The chloride content in 2, 4, 5, and 7 and the carbonate content in 1 and 6 are in excess of the amount usually permissible in a nongypseous soil. Crops were grown successfully on the land from which 3, 5, and 6 were taken, probably because of the antitoxic effect of gypsum.

Determinations of soluble carbonate, bicarbonate, and chlorine in soil of Las Vegas, Nev.

[Percentages of total soil.]

Sample.	Owner.	Location.	Soil within 1 foot of surface.			Soil between depths of 1 and 4 feet.		
			Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Chlorine (Cl).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Chlorine (Cl).
1	W. S. Park	NW. ¼ NE. ¼ sec. 22, T. 20 S., R. 62 E.	0	0.252	0.025	0	0.201	0.035
2	do	do	0	.075	.620			
3	Clark County Land Co.	Sec. 4, T. 21 S., R. 62 E.				0	.075	.128
4	Heaton	NW. ¼ sec. 1, T. 22 S., R. 62 E.	0	.117	1.93			
5	Clark & Ronnow	NW. ¼ sec. 11, T. 22 S., R. 61 E.	0	.100	.549	0	.154	.198
6	H. L. Martin	SE. ¼ SE. ¼ sec. 21, T. 20 S., R. 61 E.	0	.311	.023	0	.122	.023
[a] 7		Sec. 29, T. 21 S., R. 62 E.	0	.154	.409			

[a] Surface crust.

The following is a complete analysis of a marl composing the soil, which was collected during the excavation of the basement for the Thomas Building in Las Vegas:

Analysis of marl excavated under the Thomas Building, Las Vegas, Nev.

[Herman Harmes, State and city chemist, Salt Lake City, Utah, analyst.]

Silica (SiO_2)	10.00
Alumina (Al_2O_3)	3.58
Iron (Fe)	.09
Calcium (Ca)	30.55
Magnesium (Mg)	2.25
Sodium (Na)	.007
Potassium (K)	.000
Carbonate radicle (CO_3)	51.27
Sulphate (SO_4)	Trace.
Chlorine (Cl)	.013
Moisture at 240° F	.13
Volatile and organic matter	1.98
Loss	.10
	99.97

RAINFALL AND TEMPERATURE.

Rainfall data were collected at Las Vegas for the United States Weather Bureau from 1895 to 1900 and from 1907 to 1910. The annual precipitation for the five years for which the records are complete ranges from 1.64 inches to 5.35 inches, with an average annual precipitation of 3.39 inches. (See table below.)

The average monthly precipitation is low—in only one month exceeding one-half inch. The least rain falls during May and June and the most falls in August. The heavy rains are probably more often local, consisting of storms or cloudbursts, than general and widespread, although the rainfall stations are too widely separated to determine this fact. The greatest precipitation recorded for any month is in September, 1908, when 2 inches of rain fell. Several times since the records were begun periods of three months have elapsed with practically no rainfall. The amount of moisture in the soil produced by rains is not sufficient to be of much benefit to growing crops.

Monthly and annual precipitation, in inches, at Las Vegas, Nev.

["Tr." indicates a precipitation of 0.01 inch or less.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1895	......	......	......	......	......	0.00	Tr.	0.00	0.00	0.39	0.12	0.00	......
1896	0.11	0.06	0.36	Tr.	0.25	.00	0.61	.97	Tr.	.26	.24	.38	3.24
1897	1.71	1.67	.50	0.03	.22	.00	Tr.	.76	.02	.16	.00	.28	5.35
1898	.51	.08	Tr.	.00	.20	.20	.05	.40	.00	.00	Tr.	.20	1.64
1899	.40	.00	.00	.44	.00	.25	Tr.	.00	.00	.28	.66	.00	2.03
1900	.00	.00	.15	1.42	.00	.30	.23	.10	.00	......	......	......	......
1907	......	......	......	......	......	......	......	......	Tr.	.46	.00	.00	......
1908	.18	.09	.02	Tr.	.01	Tr.	.60	1.35	2.00	.48	.00	Tr.	4.73
1909	.40	1.12	.71	......	Tr.	.00	.18	1.78	.84	.00	.70	1.05	......
1910	......	......	.30	Tr.	.00	.00	.65	Tr.	.12	......	......	1.00	......
Average	.47	.43	.25	.27	.08	.08	.29	.59	.29	.25	.21	.32	3.39

A subtropical climate prevails in Las Vegas Valley. The growing season generally covers nine months, and the winters are usually mild. During the years 1895 to 1900 and 1907 to 1909, during which observations were made, the highest temperature recorded was 115° F., the lowest was 11° F., and the mean annual temperature was 56.8° F. On account of the aridity of the climate neither the heat of summer nor the cold of winter causes as much discomfort as in more humid climates. The high Spring Mountain Range, on the west of the valley, causes the temperature to vary widely. In summer, when the thermometer often stands above 100° F. during the day, it may fall nearly to freezing during the night. This wide variation in the annual and monthly temperatures is shown in the following table:

Temperature (° F.) at Las Vegas, Nev.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	77	78	91	91	101	111	115	110	107	94	83	73	115
Minimum	11	11	16	26	32	35	50	47	38	29	14	12	11
Mean	41.4	44	49.5	57.9	65	74.2	80.7	78.6	70.8	59.2	42.6	39.3	56.8
Range	66	67	75	65	69	76	65	63	69	65	69	61	104

GROUND WATER.

SPRINGS.

In several parts of Las Vegas Valley springs issue from the valley fill, with few exceptions from or near the bases of the terraces described on pages 31–32. Tule Springs, about 12 miles northwest of Las Vegas, issue from mounds a short distance from the highest terrace. They partake of the nature of mound springs, but they are probably associated in some way with the unconformity along the terrace. The largest of these springs has a discharge of 0.47 second-foot, as measured by a standard Cippoletti weir. Las Vegas Springs, which issue from the foot of a small terrace about 3 miles west of Las Vegas, have a reported discharge of 5.75 second-feet. Part of the water is used for the domestic and industrial supply of the town and part for irrigation on the Las Vegas ranch. The temperature of the water as it issues from the ground is reported by Peale [1] to be 73° F. A number of springs issue from the foot of the lowest terrace. (See p. 32.) Those at the Kyle ranch flow about 0.9 second-foot. Indian, Fourmile, Mesquite, Cow, and Grapevine springs each has a small discharge, which is used primarily for stock. Corn Creek Springs, which is a typical mound spring, has a discharge of 0.2 second-foot. Extending north from this spring for about 1½ miles is a series of mounds that appear to have once been the sites of knoll springs which have been closed. The presence of shallow water is shown by the luxuriant growths of grapevines, weeds, and other plants. The water from Cottonwood Spring, in the southwest part of the valley, is piped to Arden, Sloan, and Jean, where it is used for boiler and domestic purposes.

WELLS.

Distribution and character.—About 125 wells have been sunk into the valley fill. Water is found at shallow depths on the bench on which Las Vegas is situated. In September, 1912, the water was standing 12 feet below the surface in the well belonging to Frank Cliff, in "Old Town," and 9 feet below the surface in the well belong-

[1] Peale, A. C., Lists and analyses of the mineral springs of the United States: U. S. Geol. Survey Bull. 32, pp. 197–202, 1886.

ing to H. G. Helm. The deep wells that have been sunk on this bench have encountered water at similar depths. A second water-bearing stratum is reported in most of the wells about 50 to 60 feet below the surface. Usually these nonflowing waters are cased off when artesian wells are sunk.

About 100 deep wells have been sunk into the valley fill in the search for artesian water. Of this number about 75 flow and 25 do not. None of the wells, however, has failed to penetrate water-bearing beds. The deep wells range from 150 to 1,150 feet in depth and from 3 to 12 inches in diameter, but most of them are 8 inches in diameter. (See Pl. III.)

Most of the flowing wells are in the central part of the basin but not on the lowest land. This fact seems to indicate that most of the ground water comes from the Spring Mountains and that these mountains have been the source of the sediments in the valley. The material beneath the low-lying land in the eastern part of the valley seems to be finer and less pervious to water than that underlying the bench on which the artesian wells are obtained. The area in which there were flowing wells in 1912 (see Pls. I and II) covers about 65 square miles, but there has not been enough drilling in all parts of the valley to determine definitely the limits of the area in which flows could be obtained. Drilling may show that flows can be obtained farther west than is now known.

Construction.—Most of the artesian wells were drilled with the ordinary percussion drill, but a few have been sunk with hydraulic rigs. The former is regarded with favor by the drillers, because it is better adapted for penetrating gravel and bowlder beds than the latter. The holes are usually lined with iron casing to a point a few feet above the "first flow," and in a few wells smaller casing has been inserted below the first water-bearing stratum.

Cost.—The cost of drilling is approximately $1.25 a foot for the first 100 feet, with an increase of 50 cents a foot for each succeeding 100 feet. The casing ordinarily used is iron screw coupling. Eight-inch casing of this type costs about 75 cents a foot.

Capacity.—The volume of water flowing from 26 artesian wells was measured by means of a Cippoletti weir and was found to range from 0.04 to 1.37 second-feet, or from 18 to 615 gallons a minute. The greatest discharge comes from wells on the west side of the artesian area. The natural flow of many of the wells has diminished, more especially those in the southern part of the artesian area, where the water in several wells has ceased flowing and in one has sunk to a level about 6 feet below the surface of the ground.

The decrease in the discharge may to some extent be due to carelessly letting the water run to waste but is probably more largely due to improper methods in casing. It is known that water escapes

A. EGLINGTON'S FLOWING WELL.

B. BARNSLEY'S FLOWING WELL.

TWO TYPES OF FLOWING WELLS IN LAS VEGAS VALLEY, NEV.

around the outside of the casing in several wells when they are shut off. In the Eglington well (Pl. III, *A*), which has a larger flow than any other well in the valley, the water escapes in this way and has seeped into the gravel beds near the surface to such an extent that the railroad grade below the farm is rendered unsafe for heavy trains. A large proportion of the wells are cased for only a part of their depth, and as a result much valuable water is wasted. (See p. 23.)

QUALITY OF GROUND WATER.

Analyses were made of 17 samples of water (Nos. 1 to 17) from wells and springs in Las Vegas Valley, the results of which are given in the table opposite page 26. The waters have, in general, only a moderate content of mineral matter. The total solids in the samples analyzed ranged from 251 to 7,355 parts per million. The most abundant base in solution is calcium in all the waters except No. 17, in which sodium predominates. Sulphate predominates in all the waters except Nos. 1, 2, 8, 11, 12, and 16, in which bicarbonate is most abundant. Chloride and nitrate are low in all except Nos. 9 and 17. The total hardness ranges from 142 to 1,865 parts per million. All the waters, except No. 1, are poor for boiler use on account of the high content of scaling ingredients and the tendency of most of them to corrode the boiler. Nine of the samples have been classified as good for domestic use, the chief detrimental feature of the others being their large content of sulphate. The alkali coefficients (Stabler's) range from 2 to 300, 13 of the waters being classified as "good" for irrigation, 2 as "fair," and 2 as "poor."

IRRIGATION WITH GROUND WATER.

Probably most of the water that sinks into the gravelly upper slopes bordering the mountains finds its way into Colorado River, only a small proportion issuing as springs or being evaporated from the surface. A large part of this surplus ground water can be recovered through wells for irrigation. A larger supply of water could probably be obtained from artesian wells by more judicious casing, but even with this precaution the area that could be irrigated with artesian water would be rather small. If many wells are drilled in an artesian basin some of them cease to flow, and the flow of others is greatly diminished. In 1912 less than one section of land was irrigated from all the artesian wells in the valley, approximately 100 in number.

Pumping probably offers better prospects for obtaining irrigation water than do artesian flows. In 1912 three pumping plants were in use in the valley. Two are on the Clark County Land Co. ranch, in the low-lying eastern part of the valley, where artesian water can

not be obtained, and one is on the Clark & Ronnow ranch, where it is used to supplement the natural flow.

The pumping plants on the Clark County Land Co. ranch, also known as the Winterwood ranch, were not in operation at the time the ranch was visited in 1912, but the following information is furnished by O. E. Meinzer, of the United States Geological Survey, who was at the place in August, 1913.

About 14 wells have been drilled on this ranch, on secs. 3, 4, and 5, T. 21 S., R. 62 E. Most of them are about 180 feet deep, but one was sunk to a depth variously reported between 480 and 680 feet. Water-bearing beds are reported between 60 and 70 feet, at 80 feet, and at 180 feet, but not at lower levels. In the 6 wells that were measured the normal water level was found to range between 21 and 28 feet below the surface, except in the deep well, in which water was not reached with a 100-foot tape. Whether the low water level in the deep well was due to the water-bearing beds being cased off or to the low head of deep-seated waters was not ascertained.

Two of the wells, one near the southeast corner of the SE. ¼ NW. ¼ sec. 3 and the other near the northwest corner of sec. 4, are equipped with centrifugal pumps and 15-horsepower gasoline engines. They were pumped almost continuously during a considerable part of the irrigation season of 1913, but were not in operation in the latter part of August. The well on sec. 3 is equipped with a horizontal centrifugal pump installed near the water level, 21 feet below the surface, and is reported by the foreman of the ranch to have been pumped at the rate of 60 miner's inches (about 600 gallons a minute). The plant was out of repair when examined in August, 1913. The well on sec. 4 is equipped with a centrifugal or rotary pump inserted in the casing at a depth that was not ascertained and is reported by the foreman to have been tested at 72 miner's inches (about 700 gallons a minute). It was seen in operation for several hours, during which time it yielded approximately the amount reported, but there were no facilities for accurate measurement. In a disconnected well about 100 feet distant the water level stood 28 feet below the surface before pumping was begun and dropped about 2 feet when the pump was in operation. The water is not of bad quality for irrigation, as is proved by the fact that it has no saline taste. With distillate at 16 cents a gallon the two plants were operated at a cost for fuel of about $3 an acre-foot of water. The cost for attendance, repairs, and lubricating oil was not ascertained.

About 100 acres of various crops were planted in the spring of 1913, but although water was applied in ample amounts the results were disappointing. The difficulty was evidently with the soil, which is of the clayey, gypseous type. Whether this soil can be made

productive by more skillful cultural and irrigation methods remains to be demonstrated.

On the Clark & Ronnow ranch a pit was dug 18 feet deep to the first water-bearing stratum by the side of an artesian well, and a hole was drilled in the bottom of the pit to the second water-bearing bed. A 25-horsepower Fairbanks-Morse gasoline engine and a No. 5 vertical shaft centrifugal pump are used. The pump is so arranged that water can be drawn from either the artesian well or the pit, or from both simultaneously. A partial test of the plant was made in December, 1912. It was impossible to measure the drawdown in the pit on account of the small size of the hole into which the suction pipe extends. A good crop of alfalfa was raised on this ranch in 1913.

Pumping test of the Clark & Ronnow well.

Source.	Discharge.		Time required to yield 1 acre-foot.	Depth to water.	Owner's estimate of cost per hour for fuel and oil.	Cost per acre-foot.
	Sec.-ft.	*Galls. per min.*	*Hours.*	*Feet.*		
Pit	0.63	284	19	16.4	$0.20	$3.80
Artesian well	.96	432	12½			
Pit and artesian well	1.37	615	8.8			
Natural flow of artesian well	.71	320	17			

VIRGIN RIVER DRAINAGE BASIN.

MEADOW VALLEY DRAINAGE BASIN.

LOCATION AND AREA.

The Meadow Valley drainage basin is about 145 miles long and drains an area of about 3,600 square miles. It heads at the north end of Duck Valley, but is joined above Panaca by Ursine Valley and at Caliente by Clover Valley. South of Caliente it descends for the most part through a rock canyon and joins Muddy River south of Moapa. (See Pl. I.)

DUCK VALLEY.

LOCATION AND EXTENT.

Duck Valley occupies a structural trough lying between the Ely and Schell Creek ranges on the west and the Cedar and Fortification ranges on the east. It is 65 to 70 miles long, ranges from 6 to 12 miles in width, and comprises about 400 square miles of arable land. It is most easily reached over the San Pedro, Los Angeles & Salt Lake Railroad, a branch line being operated between Caliente on the main line and the mining town of Pioche. Its name is not well established, and it is sometimes called Lake Valley or Geyser Valley.

TOPOGRAPHY.

Duck Valley is separated from Spring Valley on the north by a low divide and from Meadow Valley on the south by the Pioche Range. The mountains on the west reach altitudes of 9,000 to 10,000 feet in their highest points. They form a continuous wall, except that they are partly separated by a pass a few miles southwest of Geyser, at the old Patterson mine, the mountains north of the pass being known as the Schell Creek Range and those south of it as the Ely Range. The latter range is crossed by two passes leading into the valley to the west, one a few miles north of Royal and the other about 20 miles southwest of Geyser. The Fortification Mountains constitute a range of low hills which lie opposite Geyser and separate Duck Valley from the south end of Spring Valley. The Cedar Range is somewhat higher than the Fortification Mountains and culminate in Wilson Peak, which is about 10,000 feet above sea level. The two ranges are separated by a pass that leads into the south end of Spring Valley. At the south end of Duck Valley is the Pioche Range, on the side of which the town of Pioche is located. This range is only a few miles distant from the Highland Range, from which it is separated by a narrow valley.

The northern part of Duck Valley is a typical débris-filled basin whose smooth alluvial slopes are almost untouched by erosion. This part of the valley was once the site of a fresh-water lake that extended from about the latitude of Poney Spring to a point north of Geyser post office. This lake was about 20 miles long and 15 miles wide, its position being marked by well-preserved shore features. A few small ponds in the vicinity of Wambolt's ranch are all that remain of the ancient lake. During the humid Pleistocene epoch this lake was drained southward into Meadow Valley through a channel about 50 feet deep and one-fourth mile wide. This channel begins at about the latitude of Poney Spring and becomes progressively deeper toward the south. East of Pioche Range it is about 100 feet deep in places and is cut through bedrock. It enters Meadow Valley at Delmue's ranch. The alluvial slopes bordering this channel have been dissected by streams entering from the mountains, the branch channels being cut down to a level accordant with the main channel.

GEOLOGY.

The Ely and Schell Creek ranges are composed of rocks that, according to Spurr,[1] are Cambrian, Devonian, and Carboniferous in age. The rocks consist mainly of limestones, quartzites, and shales and dip west and southwest. The Cedar Range, which borders the valley on the east, contains a great amount of lava, volcanic tuff, and rhyolite.

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[1] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel: U. S. Geol. Survey Bull. 208, pp. 38-44, 1903.

The valley fill is probably largely Tertiary in age and consists of sand, clay, and gravel, which has been changed to caliche in some places. In most of the valley the Tertiary material is overlain by Pleistocene débris. Outcrops of valley fill are found along the ancient river channel in the southern part of the valley, where clay, sand, and gravel are exposed.

VEGETATION.

The native vegetation in Duck Valley consists chiefly of the drought-resistant shadscale and blue and white sagebrush and, in the shallow-water tracts of rabbit brush and greasewood. On the upper part of the alluvial slopes juniper is prevalent, and on the mountains piñon, mahogany, and cedar are to be found.

INDUSTRIAL AND AGRICULTURAL DEVELOPMENT.

The principal industry of this immediate region has been mining, at least five mining camps having been operated at different times. Perhaps the most important were the mines at the town of Pioche, which was settled in 1869 and became a city of 10,000 inhabitants by 1872. Royal, Bristol, Patterson, and Silver Park have each been rich mining towns, but all have been abandoned except Royal.

Very little agricultural development has taken place in the valley proper, stock raising being the principal industry next to mining. The Geyser and Wambolt ranches at the north end are the only ones in the valley and they are used principally for stock raising.

Dry farming is in the experimental stage at present and is being tried on a small scale. The Valley View Farming Co. has undertaken this method of farming on a tract of 6,000 acres lying on the opposite side of the valley from Poney Spring. The attempt was fairly successful in 1912, the first year of the experiment and the only year concerning which reports have been received. Oats, wheat, and potatoes were the principal crops raised. If the precipitation, which averaged 11.99 inches at Pioche during the years 1878 to 1882, 1888 to 1890, 1892, and 1906, and 7.31 inches at Geyser during the years 1905 to 1907 and 1910 to 1912, proves sufficient to produce crops by dry-farming methods, the agricultural output of the valley may become important.

WATER SUPPLIES.

Streams.—Permanent streams are few and small and are found only in the larger canyons. Issuing from the Cedar Mountains on the east side of the valley are Craw, Wilson, and Wines creeks, and issuing from the Schell Creek Range above the Geyser and Wambolt ranches are Timber and North creeks, the latter being reported to flow about 3 second-feet. These streams are highly important

as watering places for stock but are not important for irrigation on account of their small flow during the irrigating season.

Considerable water flows down the ancient river channel during floods. The inhabitants of Pioche report that it has carried a stream 2 to 3 feet deep a number of times since the valley was first settled.

Springs.—Most of the springs are at the north end of the valley. A large number of pool and knoll springs are situated on the Wambolt and Geyser ranches at the foot of the slope bordering the Schell Creek Range. A spring of peculiar interest occurs on the alluvial slope at this place. It is locally known as the Geyser Spring, from the fact that it has an intermittent discharge. Its discharge averages about 2 second-feet but fluctuates from about 1 second-foot to 3 second-feet every three or four hours. It issues from a gravel bed at the head of a small arroyo which starts at the foot of a small terrace. The cause of the variation in discharge is not known but may be accounted for, as in some other intermittent springs, by assuming that there is a siphon in the rocks from which the water probably heads. If the water were heated it would be reasonable to suppose that it was brought about by steam action, but the water has a temperature of only 54° F.

Poney Spring is a typical seepage spring which issues from a sand and gravel bed on the alluvial slope bordering the Ely Range and has a discharge of only a few gallons per minute. Considerable excavating has been done at the spring in attempts to increase the flow. The water is used only by range stock and occasionally by campers.

The water supply for the town of Pioche is piped from Floral, Connor, and Lime springs, in the Highland Mountains. The quantity of water obtained from these springs is not known, but it is reported that there has never been a shortage in the supply nor any sickness which could be traced to the water.

Wells.—Wells have been sunk into the valley fill in search of water for domestic and stock use and have been generally successful. A dug well on the Wambolt ranch is 27 feet deep and ordinarily holds 19 feet of water, but it is reported that in the spring of the year the water rises to within 3 feet of the surface. The well on the Valley View Farming Co.'s ranch is 134 feet deep and holds 7 feet of water, which is lifted by a 4-horsepower gasoline engine operating a suction pump. Officers of the company report that 1,800 gallons a day have been used for several successive days without materially depleting the supply. Altogether at least eight wells have been sunk in the old river channel, six of which have been successful and two unsuccessful. Five of these are locally known by names expressing their distance from Pioche. (See Pl. I.) At the point where the road

leaves the old river channel, 21 miles from Pioche, a hole was dug to a depth of 90 feet, but failed to obtain water. Six miles farther south, or 15 miles from Pioche, a dug well obtained at a depth of 48 feet a good supply, which is still used for watering cattle pastured in the valley. In a depression about a mile northwest of the 15-mile well two wells were drilled which supplied the mining camp at Royal when it was flourishing but which have not been used for a number of years. They are reported to be 150 feet deep, but this report has not been verified. The 8-mile well is 28 feet deep and holds 6 feet of water. The 6-mile well is about 22 feet deep and the 4-mile well only about 18 feet deep. It is reported that in the mines at Pioche water was struck at a depth of about 1,100 feet.

QUALITY OF WATER.

As shown by analyses 21, 22, and 42 in the table opposite page 30, the waters are of fairly good quality. Calcium is the most abundant base and bicarbonate the most abundant acid radicle in the samples analyzed. The Wambolt spring water and the municipal supply for Pioche are poor for boiler use because of their high content of scale-forming ingredients, but they are good for domestic use. Their alkali coefficients are high and they are therefore of good quality for irrigation. The Geyser Spring water is fair for boiler use, for it contains only a moderate amount of scale-forming ingredients, and it is good for both domestic use and irrigation.

IRRIGATION WITH GROUND WATER.

No attempt has been made in this valley to utilize the ground water for irrigation. The water table is near the surface over most of the axial part of the valley, and with careful management the ground water could be profitably pumped for irrigation in some localities. In the southern part of the valley the water could be profitably pumped for the irrigation of crops to supply the market at the local mines. The hay, grain, fruit, and garden produce is at present shipped to Pioche by railroad, most of it being hauled for long distances at high cost. It could well be produced at home.

No experiments have been made to determine the quantity of ground water available, but the physical conditions indicate that considerable supplies could be developed. In the northern part of the valley, at the Geyser and Wambolt ranches, a large quantity of water is annually wasted in irrigating meadow land. A part of this water might be intercepted in its course through the ground and used to irrigate field crops on the alluvial slopes.

URSINE VALLEY.

LOCATION.

Ursine Valley occupies the trough at the head of Meadow Valley Wash. It lies on the east side of the Cedar Range and extends northward from Delmue's ranch for about 30 miles. It is most easily reached from Duck and Meadow valleys, with which it is contiguous. Locally it is regarded as consisting of five successive small valleys which are known as Dry, Rose, Eagle, Spring, and Camp, but as it is a single structural and physiographic unit the name Ursine Valley is a convenient designation for it (see Pl. I), the village of Ursine being the principal settlement in the valley. In some of the older reports this valley is called Cedar Valley, but this name should not be perpetuated in the literature because it lacks individuality and is not locally recognized.

TOPOGRAPHY.

The mountains on each side of this valley are high and steep, occasionally uniting to form rock canyons. The valley has an average width of about one-fourth mile, but in two places it is about 2 miles wide. The mountains on the west have been described in connection with the description of Duck Valley. (See p. 44.) The mountains on the east are mostly rolling, and in a few places rise 8,000 or 9,000 feet above sea level.

GEOLOGY.

The geology of the Cedar Range has already been noted. (See p. 44.) The mountains on the east side of the valley, according to Spurr,[1] are composed chiefly of Tertiary volcanics but contain some older limestones of probable Paleozoic age. The valley fill is more recent and consists largely of clay and gravel.

VEGETATION.

The native vegetation consists largely of willows, cottonwoods, and sagebrush. The mountain sides are covered with small juniper, piñon, and cedars, and some of the higher mountains bear a luxuriant growth of timber.

INDUSTRIAL AND AGRICULTURAL DEVELOPMENT.

Nearly all of the inhabitants of the valley are engaged in farming and stock raising. The first settlement was made at Ursine in Eagle Valley in 1864 by Mormons from Utah, who have resided there continuously since that date. Good crops of alfalfa, grain, and fruit are

[1] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel: U. S. Geol. Survey Bull. 208, pp. 36-37, 1903.

annually raised, though damaging frosts are not uncommon throughout the year.

Dry farming is being practiced on a small scale and, from present indications, may be carried on successfully. A large part of the valley is as yet unsettled, and should this method prove successful its agricultural possibilities will be greatly enlarged.

WATER SUPPLY.

Most of the water now used in the valley is derived from the natural flow of the creek, which is supplied by innumerable small seepage springs. The largest spring issues from limestone at the head of Camp Valley on the Hammond ranch, the water having a temperature of 84° F. The other springs in the valley, although numerous, are too small to deserve individual mention. Several wells, all of them shallow, furnish an ample supply of water for domestic and stock use. No well has failed to find water. Most of the valley is supplied with stream water for irrigation, and it will probably be feasible to irrigate the portion at present uncultivated by means of ground water or to cultivate it by dry farming.

The ground water has not been sufficiently developed to justify any definite conclusions concerning it. The geologic conditions and the development, so far as it goes, indicate, however, that it comes from a thin bed of unconsolidated sediments resting on impervious bedrock. Future development will probably prove that it is easily available for irrigation. Irrigation with ground water affords greater returns at less labor than dry farming and would therefore be of more economic value.

MEADOW VALLEY.

LOCATION AND EXTENT.

Meadow Valley is a small basin lying along Meadow Valley Wash between Caliente and Delmue's ranch. It is about 25 miles long from north to south and extends from the Highland and Meadow Valley ranges on the west to the Mormon Range on the east. The Pioche branch of the San Pedro, Los Angeles & Salt Lake Railroad, which extends throughout its length, renders it easily accessible and supplies good transportation facilities for marketing crops. (See Pl. I.)

TOPOGRAPHY.

Meadow Valley is bounded on the north by the Pioche Range, on the east by the Mormon Range, and on the west by the Highland and Meadow Valley ranges; on the south it grades insensibly into the Meadow Valley canyon. The valley, which is flat bottomed, has an elevation of 4,375 feet at Caliente, from which point it rises gradually

to 5,150 feet at Delmue's ranch. The ancient Meadow Valley river ran through the valley and left a flat-bottomed channel, which is bordered by steep scarps 60 to 100 feet high. The alluvial slopes rise from these scarps to the mountains in a series of more or less dissected benches. The old river channel, which forms the main portion of the arable land, is about 2 miles wide at Panaca but is much narrower at Delmue's ranch, and at Caliente it is probably not over 100 yards in width. The successive terraces on the alluvial slopes are not unlike those found in Las Vegas Valley, except that they are closer together and therefore more noticeable. The highest well-marked terrace is near Bennetts Spring, which has an elevation of 5,600 feet above sea level or about 900 feet above the bottom of the valley.

GEOLOGY.

The Highland and Meadow Valley ranges are composed chiefly of limestone, shale, and quartzite of Paleozoic age, the Highland Range consisting chiefly of Cambrian and the Meadow Valley Range largely of Carboniferous strata. The Mormon Range on the east side of the valley is composed largely of limestone of Carboniferous age. The Pioche Range, which is a simple anticlinal fold, is composed of limestone, shale, and quartzite of Cambrian and Carboniferous ages.

The valley fill consists largely of gravel, sand, and variously colored clay. Its depth is probably great. There are good exposures of the unconsolidated sediments in the valley, but no fossils have been found to give a definite clue as to the age. The three terraces on the alluvial slopes indicate that there have been at least three epochs of accumulation, which alternated with three epochs of erosion. The terraces and the erosional features in general are very similar to, and probably were formed contemporaneous with, those in Las Vegas Valley, which are thought to be Pleistocene in age. (See pp. 31–32.)

INDUSTRIAL AND AGRICULTURAL DEVELOPMENT.

The first settlement in Meadow Valley was made in 1863 by the Mormons, who still form the majority of the inhabitants. The population in 1910 was 300, most of whom live in the town of Panaca. The people are engaged mainly in agricultural pursuits, but pay considerable attention to stock raising. Until recently crops were raised only by irrigation, but wheat, oats, barley, and potatoes are now being cultivated by dry farming.

WATER SUPPLIES.

The water supply in this valley is derived primarily from springs. A large warm spring in the northern part of the valley supplies the settlement at Panaca. It is reported to have a discharge of about

4 second-feet, which is all that is required for present development. From Panaca to the head of the box canyon above Caliente the valley fill is well watered by a great number of seepage springs which issue from the valley fill. The greater part of the valley is devoted to the production of native grasses, on which cattle are fattened for the local market, the inhabitants being satisfied with the production of enough to meet their own needs. Bennetts Spring, 9 miles west of Panaca, is situated near the highest terrace. It issues from the valley fill a short distance from the mountains, but the temperature of its water, which is 70° F., indicates that it has a deep source, probably coming from the limestone. It consists of two small springs about 100 yards apart, which are used mainly for watering stock.

Water can doubtless be obtained from wells, especially on the west side of the valley, where, on the Hans Olsen farm, a well has been dug which furnishes enough water for domestic and stock use. So far as could be ascertained this is the only well in the valley.

An analysis of the warm spring water collected at its source north of Panaca is given in the table opposite page 30 (analysis 23). Calcium is the most abundant base and the bicarbonate the most abundant acid radicle. It is moderately low in hardening constituents and total solids. It is poor for boiler use but good for domestic use and irrigation.

In order to attain the greatest productivity the valley proper should be drained by an adequate system of ditches, which would dispose of the excess water and alkali. The spring water should be led through well-constructed ditches along the margins of the valley at a sufficient elevation to be advantageously applied to the land. If the springs do not yield enough to irrigate the entire valley, additional supplies can be developed at moderate cost by pumping from the drainage ditches or from wells. Crops can be raised that will be more valuable than the wild grass that now grows in much of the irrigable part of the valley.

MEADOW VALLEY CANYON.

TOPOGRAPHY.

Meadow Valley Wash leads from Caliente through a narrow rock canyon that becomes progressively deeper toward the south. Immediately south of Caliente the walls of this canyon are only about 500 feet high, but so steep is the gradient that at Kiernan's ranch, several miles to the south, they are at least 2,000 feet high. According to Spurr,[1] the canyon was "cut in a broad north-south plateau valley separating the Meadow Valley Range on the west from the Mormon Range on the east." The plateau, he thought, was formed

[1] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel: U. S. Geol. Survey Bull. 208, pp. 139-140, 1903.

long before the canyon, probably in Tertiary time. A few miles below Kiernan's ranch the canyon broadens somewhat and forms a débris-filled basin about 1 mile wide and about 6 miles long, but at Carp a narrow but shallower canyon begins and grows progressively deeper to the lower Cane Spring, below which it again widens and becomes shallower until at the junction with Muddy River it is 2 miles wide. (See Pl. I.)

GEOLOGY.

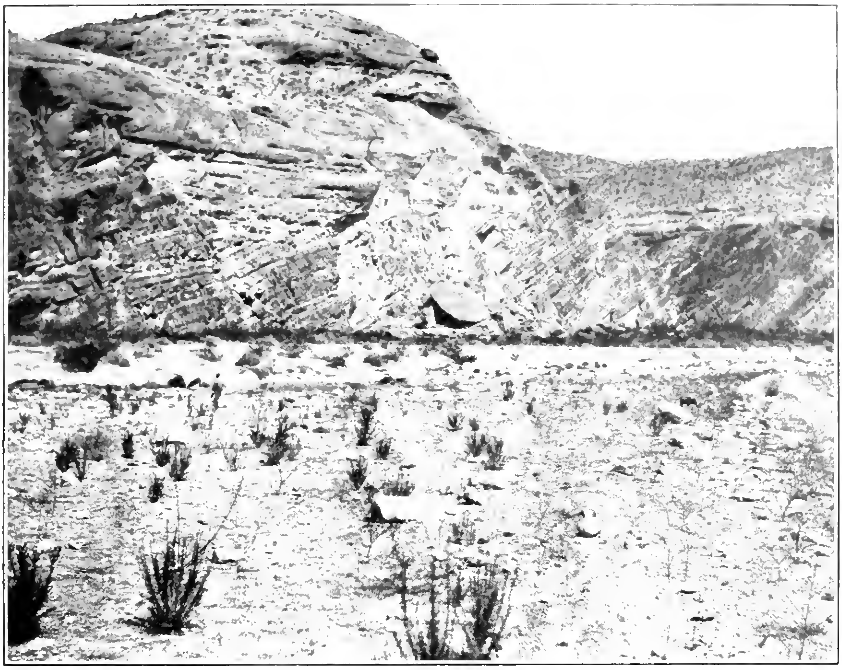
The rocks forming the walls at the north end of the canyon consist largely of igneous material, such as rhyolite, rhyolitic sandstone, and dacite. This series makes up the entire wall at Kiernan's ranch, where the canyon is probably not less than 2,000 feet deep. At Mabey's ranch, in the intermountain valley, the canyon walls are formed by stratified volcanic sandstone or tuff. Between Carp and Rox the walls are made up of inclined Paleozoic limestones, which are overlain by unconsolidated material. (See Pl. IV, *A*.) South of Lower Cane Spring the valley is cut in the red sandy clays which are described in connection with Muddy and Virgin valleys.

WATER SUPPLY.

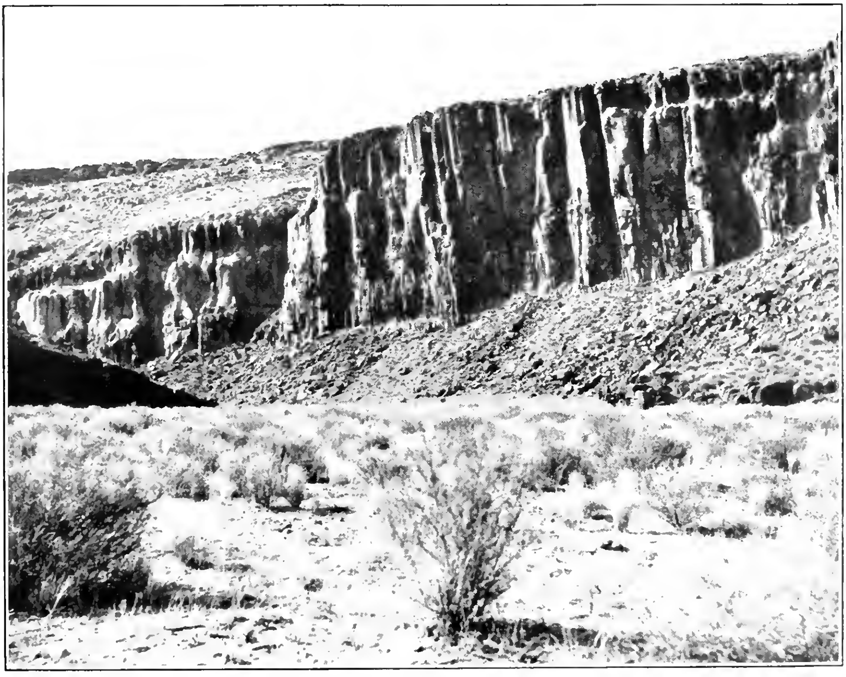
The Meadow Valley canyon is normally dry for long stretches, and during the dry part of the year no surface water reaches Muddy River. Even during the driest part of the year, however, water usually runs in some parts of the canyon, and between Caliente and Kiernan's ranch it flows throughout the year. Occasionally heavy floods sweep down the valley, carrying considerable water to Colorado River. On Carson's, Kiernan's, and Bradshaw's ranches, in the upper part of the valley, small fields are irrigated with surface water derived from the wash.

At Caliente, Carp, and Rox wells have been sunk in the bottom of Meadow Valley Wash by the San Pedro, Los Angeles & Salt Lake Railroad Co. to obtain water for locomotives. The well at Caliente is 117 feet deep, and the depth to water varies from 1 to 18 feet below the surface. The water is raised by an air lift, which supplies 300 gallons a minute. The well at Carp is 42 feet deep and 19 feet in diameter, and the water stands 34 feet below the surface. The capacity of the well is reported by the railroad company to be 100 gallons a minute. The well at Rox is 14 feet deep and 7½ feet square, and the water stands practically at the surface. The capacity of this well is reported to be 500 gallons a minute. Each of the railroad wells is located in the bottom of Meadow Valley Wash and penetrates only unconsolidated material.

The log of the Caliente well is as follows:



A. UNCONFORMITY BETWEEN PALEOZOIC AND TERTIARY STRATA IN MEADOW VALLEY CANYON, NEAR ROX, NEV.



B. ENTRANCE TO STREAM CHANNEL THROUGH BASALTIC LAVA ABOUT 24 MILES NORTH OF HIKO, NEV.

Carved by ancient White River.

Log of railroad well at Caliente.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil, sandy	5	5
Quicksand, water bearing	30	35
Clay, brown	71	106
Gravel, water bearing	11	117
Bedrock.		

In the little intermountain valley, only about 1 mile wide and 6 miles long, between Kiernan's ranch and Carp station, three wells have been sunk, in which the water was found near enough to the surface to be profitably pumped for irrigation. These wells range from 20 to 30 feet in depth, and the depth to water ranges from 14 to 25 feet, depending on the altitude of the well mouth above the stream channel. Water normally flows in the canyon above this valley, but sinks into the loose gravel which underlies the valley and flows therein at depths from which it can be profitably pumped.

WHITE RIVER DRAINAGE BASIN.

LOCATION AND EXTENT.

The White River drainage basin extends from about the latitude of Ely to the head of Muddy Valley, which is a continuation of the same drainage basin. It includes the White River, Pahranagat, and Coyote Spring valleys and some intermediate areas to which no names have been applied. The total length of the basin as here defined is about 175 miles, and its total area about 3,000 square miles, including all of the mountain and valley tracts that drain into it. (See Pl. I.)

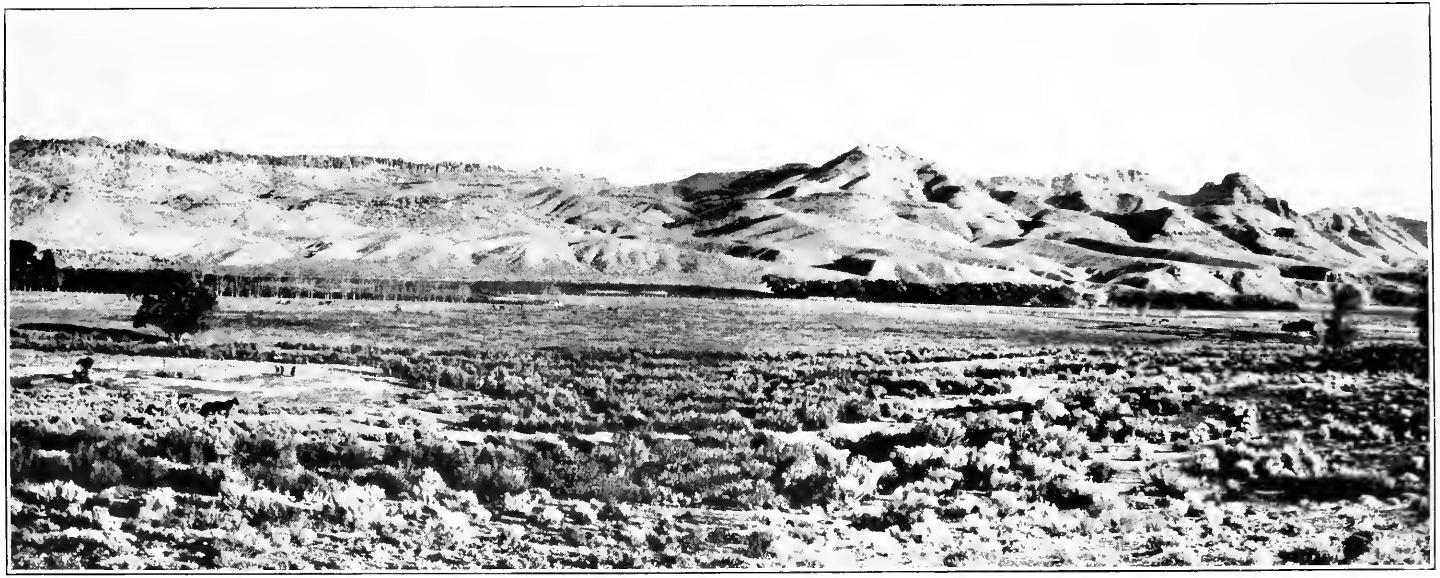
TOPOGRAPHY.

The mountains on the east side of the White River basin form a practically continuous chain. Nevertheless, different parts of them have become known by local names—the Egan on the north, the Pahroc in the center, and the Hiko on the south—names that have become firmly fixed in the minds of the inhabitants. The mountains on the west side of the basin are not continuous. The west boundary of the White River valley proper is formed by the White Pine and Grant ranges, which are continuous with the Quinn Canyon Range. South of the "sinks" of White River the valley swings eastward around the north end of the Seaman Range. West of Hiko and Alamo the west boundary is formed by the Pahranagat Range; south of Maynard Lake it is formed by the Arrow Canyon Range; and still farther south it is formed by the Las Vegas Range.

After the formation of this structural trough the agents of erosion began carrying material from the mountains and depositing it in the valley. This process continued for a long time and the valley was filled to a higher level than at present. During the humid Pleistocene epoch, when the region received more abundant rainfall than at present, a stream of considerable magnitude carved a channel through the valley from Preston to the head of Muddy Valley. In a few places it cut entirely through the sediments and deeply incised the bedrock. A typical example of this erosion is exhibited a short distance south of White Rock Spring, where the stream cut the lava and tuff to a depth of 250 feet. (See Pl. IV, *B*.) About 10 miles north of Hiko, between Fossil Peak and the Hiko Range, this stream again cut into the lava and limestone. Seven miles south of Alamo it cut a channel 75 feet deep in solid basaltic lava, and at Maynard Lake it cut another, also in lava, which is estimated to be about 500 feet deep. Thirteen miles south of Coyote Spring it cut into solid limestone to a depth of 100 feet, and about 1½ miles above Baldwin's ranch in Muddy Valley it cut the Arrow Canyon, a very steep-sided gash about 5 miles long and 500 feet deep, so narrow in places that a wagon and team can not be driven between its walls.

Throughout the length of the valley the channel is cut into the unconsolidated sediments to a depth ranging from a few feet to 50 feet or more and an average width of about one-fourth mile. In the vicinity of Preston it is only a few feet deep, and from Preston southward to Emigrant Springs it is about a mile wide and covered with a luxuriant growth of native grasses. It gradually becomes deeper toward the south. In Pahranagat Valley for 40 miles it is about 50 feet deep and one-fourth mile wide. (See Pl. V.) In Coyote Spring Valley it is 50 to 100 feet deep and about one-fourth mile wide. The alluvial slopes bordering this old river channel have been greatly dissected by the arroyos which head in the mountains and extend across the slopes. Since the change in climatic conditions and the consequent drying up of the ancient river the débris washed in from the mountains has partly silted up the old channel in many places, as, for example, about a mile north of Hiko, where the canyon from the Hiko Range discharges into the valley.

Pahroc Valley is a small débris-filled, nearly circular intermountain basin lying on the east side of the Hiko Range and separated from Bristol Valley farther east by a divide formed partly of rock and partly of débris. It slopes gently toward the west and drains through a canyon in the Hiko Range into the Pahranagat Valley, forming a part of the White River drainage basin.



PAHRANAGAT VALLEY SOUTH OF HIKO, NEV.

The work of the ancient White River is well illustrated at the right.

GEOLOGY.

The rocks exposed in the mountains of this basin consist mainly of sedimentary strata of Paleozoic age but include also considerable igneous material, such as lava and volcanic tuff.

The unconsolidated sediments consist of clay, sand, and gravel. They lie beneath the valleys, where they extend to unknown depths. Beds of fine powdery clay and rounded pebbles are exposed in cliffs 50 feet high along the old river channel and can also be seen in a few shallow wells.

The exposed parts of the unconsolidated sediments contain no fossils to give a clue to their age, but they are believed to be Pleistocene. The physiographic features, which have doubtless been formed by erosion, were probably produced in Pleistocene time. Lee[1] points out that the erosion of the Grand Canyon of the Colorado was probably accomplished in Pleistocene time during three successive epochs of erosion. These three epochs are represented in Meadow Valley and there is some inconclusive evidence that two of them are represented in the White River basin.

WATER SUPPLY.

Streams.—The drainage in this basin is at present limited to the run-off from the mountains. The old river channel is dry throughout the year from the sinks to Hiko Spring, a distance of 50 miles, and from Maynard Lake to Muddy Springs, a distance of about 35 miles, except during times of flood, when considerable water comes down the channel. There have been five such floods in the last 28 years at Hiko, the last being in January, 1910, when the big flood occurred in Meadow Valley. Most of the water that leaves the mountains soon sinks into the loose gravel and soil on the upper parts of the alluvial slopes, and only in exceptional freshets does water reach the central part of the basin.

Springs.—The water supplies in the White River valley are derived from springs. Arnoldson, Nicholas, and Preston springs are at Preston and furnish the irrigation and domestic supply for that settlement. They issue from the valley fill and in October, 1910, had a discharge of 12.63 second-feet.[2] The discharges of the separate springs were as follows: Arnoldson, 3.14 second-feet; Nicholas, 2.28 second-feet, and Preston 6.21 second-feet. The Lund Spring, at Lund, which had a discharge of 5.36 second-feet,[2] is the only supply for the settlement of Lund. A group known as Emigrant Springs supplies the water used on the Rearden ranch. The

[1] Lee, W. T., Geologic reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, pp. 62–67, 1908.

[2] Kearney, W. M., Bien. Rept. State Engineer Nevada, p. 249, 1913.

discharge of these springs was not ascertained accurately, but it is estimated to be 3 second-feet. The water is used for irrigating about 200 acres, most of which is meadow land. At Sunnyside six springs, known as the Butterfield and Flag springs, are used to irrigate about 300 acres. At the east base of the limestone butte a number of springs issue from the rocks and are used on the Hot Creek ranch. On the west side of the valley the Mormon Springs, owned by James Rearden, supply water for pasture land. Aside from these a great number of small seepage springs issue from the valley fill around the border of the meadow land.

There is no water in this basin between Hot Creek ranch and White Rock Spring except a few ponds, which are occasionally filled by rains. White Rock Spring issues from the volcanic tuff on the side of a canyon heading in the Seaman Range. Three springs in Pahranagat Valley, issuing from limestone, supply water for domestic use and for irrigation. Hiko Spring, at the foot of the Hiko Range, has a discharge of about 9 second-feet. Crystal Spring, 4 miles south of Hiko, flows about 7 second-feet. Ash Springs, 5 miles south of Crystal Spring, issue at the foot of the Hiko Range and have a discharge of about 20 second-feet. The water from these springs flows to Pahranagat Lake, about 20 miles to the southeast, during the winter, but in summer it is used for irrigation. After a flood, or when Pahranagat Lake has been filled, the water continues southeast and fills Maynard Lake. The next water to the south is at Coyote Spring, in Coyote Spring valley. Pahroc Spring, a small seepage spring, is the only watering place in the Pahroc Valley. It issues from the volcanic tuft and has a discharge of about 2 gallons a minute.

Wells.—Some wells, most of which obtained water at shallow depth, have been sunk in this basin. Shallow wells were dug at the Lund settlement, but the water was so poor in quality that they have all been abandoned. W. J. Gregory dug a well in sec. 14, T. 10 N., R. 62 E., at the edge of the grass meadows, obtaining water at 12 feet. No other wells are known to have been dug in the White River Valley above the "sink." In Pahranagat Valley, a few miles south of White Rock Spring, it is reported that a well 50 feet deep obtained no water. In a well 1.2 miles north of Hiko the water stands 36 feet below the surface, and in Hiko water was found on irrigated land at 5 feet. The next well to the south is at Roder's ranch, where the water stands $12\frac{1}{2}$ feet below the surface. A well on the upper Gardner ranch, on irrigated land, got water at about 10 feet. A well on the lower Gardner ranch obtained water at 11 feet. A well 40 feet deep in the lower part of Coyote Spring valley got no water.

QUALITY OF WATER.

The spring waters in the White River basin, as shown by analyses 24 to 30, in the table opposite page 30, contain only a moderate amount of dissolved solids. Calcium is the predominating base and bicarbonate the predominating acid radicle. The waters are invariably poor for boiler use but good for domestic use and irrigation. Analyses of water from a drainage ditch at Alamo and from Pahranagat Lake show a great increase in mineral content over the Ash Spring water, from which both are derived, the increase being no doubt due to the fact that the water in passing over the fields leaches some salts from the soil. The mineral content of the lake water is also greatly concentrated by evaporation and probably fluctuates with the level of the lake. In winter, when the water is not used for irrigation, the water rises about 6 feet above the level it reaches in the fall. The water from Pahranagat Lake is bad for every use.

GROUND-WATER PROSPECTS.

The conditions in the White River valley above the "sink" of White River are favorable for obtaining ground-water supplies. The mountains are high and are doubtless frequently visited by heavy rains. Much of the water thus received probably sinks into the gravelly upper portions of the alluvial slopes and gradually seeps underground to the central part of the valley, where it is returned to the surface through springs and minute pores in the ground. Part of this water, which is annually wasted by evaporation, could probably be intercepted during its course through the ground and returned to the surface, where it would produce useful crops. It is known that the water table lies near the surface in the central part of the valley, and it is probable that the lower part of the alluvial slopes are also underlain by shallow water.

In Pahranagat Valley, most of the central part of which is irrigated with spring water, no difficulty has been experienced in obtaining ground water. A large part of the land is covered with water, so that the problem there is a question of drainage rather than of irrigation. A well-constructed drainage canal to drain the swamp land would permit an increase in the agricultural output of the valley. In order to attain the greatest productivity developments should be made similar to those recommended for Meadow Valley. The valley proper should be drained by an adequate system of ditches which would dispose of the excess water and alkali. The spring water should be led through well-constructed ditches along the margins of the valley at a sufficient elevation to be advantageously applied to the land. If the springs do not yield enough to irrigate the entire valley, additional supplies can be developed at moderate cost by pumping from the

drainage ditches or from wells. Crops can be raised that will be more valuable than the wild grass that now grows in much of the irrigable part of the valley.

No wells are known to have been sunk in Pahroc Valley, and the conditions are such that it seems unlikely that any large supply can be obtained from underground sources. The altitude of the valley is high, and any water that might collect in the unconsolidated sediments would probably find an outlet into Pahranagat Valley, which lies much lower.

Coyote Spring Valley has only one watering place—the spring after which it is named. The geologic conditions indicate that at least small amounts of ground water occur in the valley. The Sheep Range on the west side of the valley is high and appears to be well timbered, indicating that it receives considerable rainfall. Some water, therefore, should be found beneath the valley, and it is probable that wells would reveal its presence.

MUDDY AND VIRGIN VALLEYS.

LOCATION.

Muddy Valley is a narrow strip of land extending along Muddy River from the springs in T. 14 S., R. 65 E., to Virgin River. About 6 miles below Moapa a rock canyon separates the Upper Muddy Valley on the north from the Lower Muddy Valley on the south. Virgin Valley, as here discussed, includes the narrow strip of land along Virgin River from the settlement of Mesquite to Colorado River. (See Pl. I.)

TOPOGRAPHY.

Muddy Valley is a narrow flood plain formed by the ancient White River. In the Upper Muddy Valley the flood plain is in most places not over a quarter of a mile wide and is bordered by a plateau or mesa. It widens somewhat below Moapa, where Meadow Valley Wash enters, but it narrows again as it approaches the rock canyon. The Lower Muddy Valley is on the average about 2 miles wide. The mesa bordering it stands several hundred feet above the flood plain and forms a conspicuous vermilion-colored cliff on each side.

GEOLOGY.

The rocks underlying the plateau and forming the walls of the northern part of the valley are probably of Tertiary age. Spurr[1] places them in the Pliocene series, and they have also been mapped as such by the Wheeler Survey. They consist mainly of clay, sand,

[1] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel: U. S. Geol. Survey Bull. 208, pp. 136–138, 1903.

and conglomerate, which appear to extend to considerable depth below the surface. At the Kaolin mine, about 4 miles southwest of Overton, the following section was taken:

Section at the Kaolin mine, 4 miles southwest of Overton.

	Feet.
Horizontally bedded series:	
Red clay and sand, unknown thickness.	
Brown conglomerate	50
Unconformity.	
Series dipping $32\frac{1}{2}°$ E.:	
White limestone	100
Red sandstone	150
Gray conglomerate	125
Red sandstone, unknown thickness.	

In the southern part of the valley, notably below St. Thomas, the rocks underlying the plateau consist of white clay, basaltic lava, and gypsum. These rocks lie unconformably below the red sand and clay forming the plateau farther north. They dip steeply to the west and apparently represent an older period of deposition.

VEGETATION.

Native vegetation in Muddy Valley consists of sagebrush, shadscale, greasewood, mesquite, quail brush, arrow weed, willow, cottonwood, and grasses. When the valley was settled in 1858 the Lower Muddy Valley was practically covered by wild grass and was at that time a grazing ground for the Indian herds. The drought-resistant shadscale and creosote and some bunch grass are the principal species found on the bench land bordering the valley. The vegetation in Virgin Valley is not essentially different from that in Muddy Valley.

RAINFALL AND TEMPERATURE.

Rainfall data have been collected in the Lower Muddy Valley for 13 years. During the six years for which the records are complete the annual precipitation ranged from 3.07 inches to 8.17 inches, the average being 5.98 inches. The average monthly precipitation ranged from 0.11 inch in June to 0.98 inch in January. The greatest monthly precipitation was in January, 1897, when 2.36 inches were recorded. The normal rainfall is not sufficient to be of material benefit to agricultural crops. The following table gives the data as recorded by the United States Weather Bureau:

Monthly precipitation, in inches, at Logan, Nev.[a]

[Tr. indicates a precipitation of 0.01 inch or less.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1895	......	......	......	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	0.43	0	......
1896	0.60	Tr.	0.60	0	Tr.	Tr.	0.58	0.48	0	0.92	......	.30	......
1897	2.27	1.91	1.24	......	1.00	Tr.	Tr.	.55	Tr.	1.55	......	......	......
1898	1.00	Tr.	Tr.	.06	......	......	0	0	......	......	......	......	......
1902	......	......	......	......	Tr.	0	Tr.	.22	0	0	1.33	.44	......
1903	.11	.24	.38	.05	Tr.	.07	.16	.58	.79	1.30	......	......	......
1906	......	......	......	......	Tr.	0	1.41	.76	.34	0	.58	1.13	......
1907	2.36	.95	1.40	.42	Tr.	0	Tr.	.13	.38	1.80	0	Tr.	7.44
1908	1.90	1.45	.70	.03	.29	Tr.	.04	.90	1.18	.44	Tr.	.58	7.51
1909	.35	1.52	.60	.16	Tr.	0	.26	1.86	.58	0	1.04	1.80	8.17
1910	.56	.10	.23	.07	Tr.	Tr.	.11	Tr.	......	.52	.94	.54	[b] 3.07
1911	.70	.63	.90	.16	0	.17	......	0	1.63	.80	0	.04	[b] 5.03
1912	0	......	1.88	.63	.06	.94	.44	0	0	.60	.10	Tr.	[b] 4.65
Average	.98	.76	.79	.15	.12	.11	.27	.14	.44	.66	.49	.53	5.98

[a] Observations from 1905 to 1908 were made at St. Thomas and from 1902 to 1903 at Rioville. Both stations are near Logan.
[b] The record covers only 11 months of the year.

Both Muddy and Virgin valleys have a subtropical climate. The summers are long and hot, the growing season normally covering from 9 to 10 months, and the winters are short and mild. During the years 1895 to 1898, 1902 and 1903, and 1906 to 1909 the maximum temperature recorded was 117°, the minimum 10°, and the mean 64.9°. The range between the highest and lowest temperatures recorded is 107°, but the monthly range between maximum and minimum is about 70°. The following table gives the temperature data as recorded by the United States Weather Bureau:

Temperature (°F.) at Logan, Nev.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Maximum	75	86	90	103	110	117	116	117	114	100	85	76	117
Minimum	11	10	19	25	29	34	49	50	34	29	19	10	10
Mean	43	49.7	54.2	64.3	71.7	82	87.7	86.6	77.3	66	52.6	44.2	64.9
Range	74	76	71	78	81	83	67	67	80	71	66	66	107

INDUSTRIAL DEVELOPMENT.

The Lower Muddy Valley was first settled in 1858 by Mormons from Utah. They resided there contentedly until 1865, when they learned that they were within the State of Nevada and were asked to pay taxes for a portion of the period during which they had resided within the State. In consequence they returned to Utah, and the valley was not again settled until 18 years later, when people from Utah came into it. In 1904 the San Pedro, Los Angeles & Salt Lake Railroad was built through this part of Nevada, crossing Muddy Valley at Moapa, and in 1912 a branch was built from Moapa to St. Thomas. Previous to the construction of this road the valley

was inaccessible except by wagon or stage over very rough mountainous roads.

The Upper Muddy Valley contains the Moapa Indian Reservation of about 1,000 acres and three other ranches. Until recently practically the only development in the Virgin Valley was at Bunkerville and Mesquite, which were settled about 1880.

WATER SUPPLY.

Surface water.—The surface-water supply of Muddy Valley is obtained from Muddy River. This stream has its source at the head of the upper Muddy Valley in a number of springs that issue from limestone crevices, a short distance from the mountains, in T. 14 S., R. 65 E., just below the Baldwin ranch. The water has a temperature of about 90°.

Discharge measurements were made by the United States Geological Survey[1] from 1904 to 1906, and also in 1910. From 1904 to 1906 the gaging station was just below the railroad crossing on Muddy River, but in 1910 it was moved to a point below the narrows. The measurements from 1904 to 1906 are too fragmentary to be of much value to the irrigator, but the records from April 22 to October 31, 1910, are complete. They are given in the following table:

Daily discharge, in second-feet, of Muddy River near Moapa, Nev., for 1910.

Day.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
1	....	100	92	64	52	35	37
2	....	98	88	68	57	35	37
3	....	97	83	67	62	35	37
4	....	93	82	65	66	35	37
5	....	97	81	64	56	37	37
6	....	101	81	60	52	37	37
7	....	101	80	57	49	37	37
8	....	101	70	54	46	39	37
9	....	101	65	55	46	39	37
10	....	101	57	55	63	39	37
11	....	100	58	56	90	39	37
12	....	98	60	59	118	39	37
13	....	96	62	60	67	40	37
14	....	96	65	61	60	40	38
15	....	97	67	61	49	41	39
16	....	97	66	62	49	42	40
17	....	97	64	59	48	43	41
18	....	97	62	56	48	42	41
19	....	95	60	60	50	41	42
20	....	93	58	60	52	40	43
21	....	93	58	59	53	40	42
22	122	92	56	59	53	39	42
23	112	91	55	59	54	37	42
24	105	88	53	60	50	35	42
25	98	85	52	60	48	34	41
26	99	83	54	59	43	34	41
27	100	81	56	57	38	34	41
28	102	84	59	55	33	35	41
29	103	87	60	54	33	37	41
30	102	89	60	54	34	37	40
31	....	91	....	53	34	....	39

[1] Leighton, M. O., Surface water supply of the Colorado River basin, 1910: U. S. Geol. Survey Water-Supply Paper 289, pp. 197–198, 1912.

The average discharge during the period of 190 days is 61.6 second-feet. The average discharge in second-feet by months is: May, 94.2; June, 65.3; July, 59.1; August, 53.3; September, 37.9; and October, 39.3. The total run-off for the period was 23,200 acre-feet. The total acreage irrigated is about 3,500 acres, or one acre for about 6.6 acre-feet of stream flow during this period.

Meadow Valley Wash, which is tributary to Muddy River, seldom contains a stream throughout its course. At times, however, due to heavy rains, cloud-bursts, or the rapid melting of snow in the drainage basin, it discharges a large volume of water into Muddy River. Perhaps the largest flood in this wash in recent times was in January, 1910, when about 85 miles of the San Pedro, Los Angeles & Salt Lake Railroad track was destroyed between Rox and Acoma. A flood of this character inundates farm land in the Lower Muddy Valley and destroys the irrigation ditches, but such damage could in a large measure be prevented by the construction of a large drainage ditch in the valley. The intermittent floods have filled the old channel of the river, compelling the excess water to spread over the valley floor.

Virgin River rises in southern Utah and flows southwestward, entering Nevada at the town of Mesquite. In its course through Nevada it flows over a bed of sand ranging in width from about a hundred yards to about half a mile. As in all similar streams, the water is not sufficient to cover the river bed, and consequently it meanders from side to side, cutting away in one place and depositing in another. Of late years it has been cutting into the farm lands of Bunkerville and Mesquite and threatening to destroy them.

A few miles above Mesquite the stream has cut a rock canyon through the mountains. It has been suggested that a dam might be thrown across the river at this point to store water which could be used to irrigate the mesa land on either side of the river. The erection of such a dam would probably not present any serious engineering difficulties, but preliminary surveys seem to indicate that the cost would be great as compared with the benefits that would be derived from it.

The domestic and irrigation supplies for the Bunkerville and Mesquite settlements are derived from Virgin River. Bunkerville has a population of 350 and has about 600 acres under cultivation, and Mesquite has a population of 300 and has 900 acres under cultivation. In addition to the supplies for these towns, which are conducted through gravity ditches, it is planned to take water from Virgin River for the irrigation of four farms between Bunkerville and Colorado River. S. W. Darling, in secs. 12 and 13, T. 16 S., R. 68 E., has two pumping plants. The one in sec. 12 has a 12-horsepower

gasoline engine and a No. 8 horizontal-shaft centrifugal pump. The pump has a 10-inch suction pipe.

Ground water.—No extensive attempt has been made to obtain ground water in the Muddy and Virgin valleys. Three shallow wells in the vicinity of Logan, one well east of Overton on the Morrison farm, one well north of St. Thomas on the Whitmore farm, and one deep well belonging to the San Pedro, Los Angeles & Salt Lake Railroad at St. Thomas constitute the ground-water development in the Muddy Valley. The only well in the Virgin Valley is at Bunkerville. The wells at Logan are driven, and the depth to water in them could not be ascertained. In the Morrison well, in the NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 19, T. 16 S., R. 68 E., the water stands 11 feet below the surface. In the Whitmore well, in sec. 33, T. 16 S., R. 68 E., the water stands 20.4 feet below the surface. In the railroad well at St. Thomas, which affords the best index of the ground-water conditions in the valley, the first water was struck at 30 feet. This water was cased out and drilling continued to a depth of 805 feet. The water stands 284 feet below the surface and is reported to bear continuous pumping at a rate of 120 gallons a minute. The well at Bunkerville, which is reported to be 60 feet deep, yields water that is too brackish to be palatable.

Ground water in Muddy Valley lies near enough to the surface to be profitably pumped for irrigation, but it is found in quicksand, which does not give up its supply readily enough to allow continuous pumping. The Morrison brothers attempted to irrigate with ground water in 1912, but the attempt was unsuccessful. In Mesilla Valley, in New Mexico, satisfactory irrigation supplies have been developed in wells ending in fine sand by sinking perforated iron casings to the desired depth, pumping out the sand in as large quantities as possible, and filling the resulting cavities, outside of the casing, with fine gravel. By this process gravel screens were developed around the well casings and water was obtained much more freely than from the fine sand. Some such method would be worthy of trial in the Muddy Valley.

QUALITY OF WATER.

The quality of the water in Muddy Valley is shown by analyses 18, 19, 20, and 41 in the table opposite page 30. The water in Muddy River, which forms the principal supply for the valley, contains 835 parts per million of dissolved solids, sodium being the most abundant base and the sulphate the most abundant acid radicle. This water is poor for boiler use on account of its high content of scaling ingredients, and it is only fair for irrigation, its alkali coefficient being 16. Chemically it is only fair for domestic use, because of its content of sulphate, and hygienically it is questionable.

The analysis of the water from the well on the Bryant Whitmore farm, north of St. Thomas (No. 41, in table opposite p. 30), gives a valuable index to the quality of the ground water in the valley. This water contains 3,053 parts per million of dissolved solids, sodium being the most abundant base and sulphate the most abundant acid radicle. It is bad for boiler use, containing 1,280 parts per million of scale-forming ingredients, 1,300 parts of foaming ingredients, and being corrosive. It is poor for domestic use on account of its high mineral content and is poor for irrigation.

The analysis of the water from the railroad well at St. Thomas probably indicates the quality of the deep-seated water beneath the valley. It contains 3,815 parts per million of dissolved solids and may be classed as a sodium sulphate water. It is very bad for boiler use because of its content of scale-forming and foaming ingredients and its corrosive action. It is bad for domestic use on account of its high mineral content, and it is poor for irrigation.

No analysis of Virgin River water was made. The quality of this water, however, is indicated to some extent by the fact that it has been used for domestic purposes for many years by the inhabitants of Bunkerville and Mesquite without ill effect. It has also been used for irrigation at these places since the first settlement in 1880 without serious injury to the land or crops.

FUTURE DEVELOPMENT.

The future development of Muddy Valley depends to a very large extent on the procuring of additional water for irrigation. Although the entire supply from Muddy River is appropriated, less than one-third the total arable land is under cultivation. With more judicious use the water now available might serve a larger acreage, but it can not be hoped that it would irrigate all the arable land in the valley. A dam constructed in the narrows would store water for the irrigation of the lower valley, but as there are only about 6,000 acres to be served the cost makes such a dam hardly feasible. The low alkali coefficient of the ground water probably precludes its use for irrigation. Possibly it could be used by applying the surface waters, when abundant, to wash out of the soil the alkali deposited by the ground water.

The present method of distributing the water does not give good results. A large drainage ditch is needed throughout the valley to prevent destructive floods. The canals should be placed higher on the sides of the valley and should be better constructed in order to prevent seepage and frequent breaks. The seepage collected in the main drainage ditch could be led or pumped upon land lower down the valley and used a second time for irrigation.

GREAT BASIN DRAINAGE.

BRISTOL AND DELAMAR VALLEYS.

LOCATION AND EXTENT.

Between the Meadow Valley and White River drainage systems, which head far north but discharge into Virgin River and thus form a part of the Colorado River system, lies a rock trough about 65 miles long and 8 miles in average width, which has no drainage outlet and therefore constitutes a long tongue of the Great Basin province. This trough is bordered on the east by the Ely, Highland, and Meadow Valley ranges and on the west by the Pahroc and Hiko ranges. About 8 miles north of Delamar this trough is crossed by a low alluvial divide that separates it into two independent drainage basins. On the old maps of Nevada this trough is called Desert Valley, but as this name is frequently applied to other valleys in this region and is not distinctive it is desirable to substitute for it names of local significance. In this report the name Bristol Valley is applied to the northern basin and Delamar Valley to the southern. The names are suggested by the two old mining camps in the respective basins, and both have the sanction of considerable local usage.

TOPOGRAPHY.

There is a very striking difference between the topographic features exhibited in these valleys and those drained by Colorado River. In Bristol and Delamar valleys the alluvial slopes are smooth and grade down into the central flat almost imperceptibly. The few streams that issue from the mountain canyons in times of flood carve channels into the upper part of the alluvial slopes but gradually play out toward the central flat. In the valleys drained by Colorado River and its tributaries, on the other hand, the alluvial slopes are greatly dissected, the streams that issue from the mountain canyons in times of flood carve channels which usually become deeper toward the central part of the valley, and the central flats are usually more or less dissected and much narrower than those in the inclosed basins.

The lowest parts of Bristol and Delamar valleys are occupied by large playas or mud flats, and there is evidence that both were once the beds of lakes. These lakes were small in comparison with some of the other Pleistocene lakes in the Great Basin, such as Lake Bonneville and Lake Lahontan, but contained considerable water.

Only the southern part of the ancient lake bed in Bristol Valley was seen, but it probably covered an area of about 50 square miles, including the present dry lake and adjoining area. When at its maximum height it was about 75 feet deep and had a shore line perhaps 40 miles

in length. It stood at high-water mark long enough to carve a terrace about 8 feet high on the lower part of the alluvial slopes.

Delamar Lake was about 50 feet deep and covered an area of about 55 square miles. Its shore line was about 35 miles long and it covered all of the present dry lake and contiguous surrounding area. It carved only slight shore features, which might be overlooked by one unaccustomed to such phenomena. The best exposure of the shore features is on the small butte about 12 miles southwest of Delamar, where the waves of the ancient lake cut a notch into the solid limestone.

RAINFALL AND VEGETATION.

No observations have been made of the precipitation in these valleys, but the scant vegetation shows that it is slight. In Bristol Valley on the upper parts of the alluvial slopes, where the rainfall is no doubt greater than in the low part of the valley and the run-off from the mountains may have an influence on the soil moisture, the common sage predominates, but in the lower part of the alluvial slopes and on the central flat shadscale and white sage form much the greater proportion of the vegetation. In Delamar Valley the alluvial slopes are practically covered with a species of Spanish bayonet and yucca locally called Joshua trees, and the central flat by a very scant growth of white sage, shadscale, and bunch grass. The playas or so-called "dry lakes" in both valleys are covered with water for a short time after the heavy rains and are practically destitute of vegetation.

WATER SUPPLY.

Wells and springs.—Bristol and Delamar valleys are entirely destitute of irrigation supplies and contain only a few watering places for man or beast. One well and three springs constitute the only permanent supplies in these valleys.

Bristol well formerly furnished the water supply for a smelter which was located there on account of the water. It is reported that several wells were dug and a small town sprang up around them, but one well and some stone buildings are all that remain of the former village. This well has been kept in use ever since by the traveling public and by the miners at the Bristol mine, a few miles to the east, who haul the water for domestic use from here. It is located in a small ditch which leads through a gap in a range of hills a short distance to the southwest. It is 51 feet deep and in October, 1912, the water stood 43 feet below the surface. The rock formations that outcrop in the hills in the vicinity doubtless act as an underground dam to hold back the ground water that sinks into the alluvial slopes at the foot of the Ely Range. The quantity of water that the well will furnish is small, as is shown by the fact that it is frequently pumped dry by the miners

in filling the water tanks which they use in hauling supplies to the mine.

Bailey Spring is situated above the Adams & McGill cattle camp, 5½ miles northwest of the Bristol well (Pl. I). It is a small seepage spring issuing from bedrock at the top of the alluvial slope and has been developed by excavating. The supply, which amounts to only about 3 gallons a minute but is of good quality, is led a short distance down the slope to the camp.

Maloy Spring lies 6 miles north of Bailey Spring (Pl. I) and is probably produced by similar conditions. It was, however, not visited by the writer and no authentic data were obtained concerning it.

Coyote Spring lies about 8 miles southwest of the Bristol well (Pl. I) and issues from the alluvium above a bed of lava. It flows about 5 gallons a minute and is used for watering the stock on the range. A house and corral have been built near the spring, but neither appears to have been used for some time.

The water for Delamar is piped from Squaw, Baker, Nesbit, and Horn springs, which are reported to be small seepages in the limestone and granite. When the mine at this place was in active operation the water supply was obtained in the Meadow Valley Wash and was pumped over the Meadow Valley Range through two 3½-inch pipe lines, but these lines are no longer in existence.

Ground water.—Conditions are not favorable for finding very large quantities of ground water in these valleys. It is true that the basin is a trough which appears to be incased in bedrock, but the water seems to escape to Pahranagat Valley, probably through a fissure or along a fault plane in the Hiko Range. No wells are known to have been dug in Bristol Valley except the one near the Bristol mine (p. 66), and the yield of this is small. The mine at Delamar, which is 1,400 feet deep, is totally dry, and a well reported to have been drilled 900 feet deep at the foot of the alluvial slope, 1,100 feet lower than the mine, is also reported to have been dry. The water that sinks into the upper part of the alluvial slopes probably finds an outlet into the Pahranagat Valley. The analysis of the water from Bristol well is given in the table opposite page 30 (analysis 39). It is poor for boiler and domestic uses but has a high alkali coefficient and is therefore good for irrigation.

COAL VALLEY.

LOCATION AND AREA.

Coal Valley is an uninhabited trough between the Seaman Range on the east and the Golden Gate Range on the west. It is about 25 miles long and 8 miles wide and contains about 200 square miles of valley land. It grades insensibly into Garden Valley through a number of gaps in the northern part of the Golden Gate Range. The

roads leading to Cherry Creek from Pioche and Hiko unite at a point called Oneota in the west-central part of the valley.

TOPOGRAPHY.

Coal Valley is bounded on the east by the Seaman Range, which rises 2,000 to 3,000 feet above the valley floor, and on the west by the Golden Gate Range, which rises to only 1,500 to 2,000 feet above the valley. The south boundary is formed by the spur which connects Fossil Peak with Pahranagat Range, and the north boundary is formed by an alluvial divide between the north ends of the Seaman and Golden Gate ranges. The northern part of the Golden Gate Range consists of a series of low hills which are entirely detached from one another and separated by narrow stretches of valley deposits.

The most important topographic features in the valley are distinct terraces and beaches, which were produced by the waves of an ancient lake and which can be plainly seen on all sides of the central flat. At its period of greatest extension this lake was about 14 miles long and 6 miles wide and covered an area of about 100 square miles. Its maximum depth at this period was about 75 feet, and the length of its shore line was about 40 miles (Pl. I). The ground surrounding these shore features extends to higher levels, showing that the lake had no outlet and that the water was probably salt. The central part of the valley is in general flat and barren. On the western side, where it is underlain chiefly by clay, the flat has been extensively carved by the wind into a number of shallow basins. There are no mud or alkali tracts such as are usually found in closed basins, except a few minor holes where surface water stands after heavy rains.

GEOLOGY.

The southern part of the Seaman Range is composed of lava and volcanic tuff, but the northern part is composed largely of limestone, probably of Paleozoic age. The Golden Gate Range is composed mainly of limestone which Spurr [1] regarded as Paleozoic in age. The valley fill is composed of sand, clay, gravel, and bowlders which have been washed from the surrounding mountains and which extend to an unknown depth below the surface. It is reported that a hole was dug at Oneota to a depth of 250 feet without reaching bedrock. The material lying within the shore lines is mostly fine clay and sand which was deposited in the relatively quiet waters of the lake. This lake probably existed in Pleistocene time and was correlative with Lake Bonneville. Unconsolidated sediments exposed in the valley are Pleistocene and Recent in age, but the underlying sediments may be Tertiary.

[1] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel: U. S. Geol. Survey Bull. 208, pp. 57-59, 1903.

VEGETATION.

The native vegetation in Coal Valley consists chiefly of drought-resisting types such as shadscale and white sage. Considerable bunch grass is found in the lower part of the basin, but this grass would probably soon be destroyed if it were near enough to a water supply to be reached by range stock. The mountains bordering the valley are practically barren of timber except for a few cedars on the pass between Pahranagat and Coal valleys and on the mountains at the south end of the valley.

WATER SUPPLY.

Coal Valley is one of the driest basins in southeastern Nevada, only one small spring being present in an area of about 225 square miles. Its present aspect is in strange contrast to what it must have been when it contained the Pleistocene lake.

The absence of alkali flats or seeps proves the absence of shallow water, and an excavation at Oneota, only about 50 feet above the lowest part of the valley, though reported to be 250 feet deep, failed to reveal any ground water. The lowest part of Coal Valley is about 4,550 feet above sea level, or about 225 feet higher than Pahranagat Valley. Any water that might collect in the unconsolidated sediments would be likely to find an underground passage through the bedrock formations into the unconsolidated material underlying Pahranagat Valley, but it would not be expected that the water level would be at a lower altitude above sea level in Coal Valley than in the adjacent valleys, where the sediments are known to be saturated practically to the surface. It seems reasonable to expect that deep drilling will reveal the presence of water below some level in the unconsolidated sediments, as it has in Dry Lake Valley, which is analogously situated. The vicinity of Oneota seems to offer the best possibilities of finding water because the run-off from the lofty Grant and Quinn Canyon ranges enters the valley in this locality.

Seaman Spring, which issues from rhyolite in the southwest part of the Seaman Range, is the only permanent watering place in the valley. It is about 2 miles on an air line north of the pass leading into Pahranagat Valley and about 1 mile east of three limestone knolls which project through the unconsolidated sediments in the southeast part of the valley. It has a discharge of about one-half gallon per minute and flows into troughs used for watering stock.

GARDEN VALLEY.

GENERAL FEATURES.

Garden Valley is bordered on the west by the Quinn Canyon, Grant, and Worthington ranges, and on the east by Golden Gate Range. It drains into Coal Valley through a gap in the Golden Gate

Range and is separated from the White River valley on the north by only an alluvial divide (Pl. I). The valley is properly an alluvial slope, which has been formed of débris washed from the mountains. On account of the greater altitude of the mountains on the west side of the valley, most of the débris has been derived from them, with the result that the valley slopes eastward to the Golden Gate Range, partly burying it in unconsolidated material. The drainage is thus all to the eastward. Cottonwood and Cherry creeks, which head in the Quinn Canyon Range (Pl. I), have carved shallow channels, which cross the slope, unite near the east side, and discharge through the gap in the Golden Gate Range.

WATER SUPPLY.

Surface water.—Garden Valley contains no irrigation supplies, except the surface waters of Cherry and Cottonwood creeks. Cherry Creek has a flow of about 8 second-feet and Cottonwood Creek a flow of about 3 second-feet, but the water is used on the land along the stream courses before it reaches the valley proper. In fact, the water reaches the lowest part of the valley only during exceptionally large floods.

Ground water.—Conditions are not favorable for finding ground water in this valley in very large quantities. The gradient of the alluvial slopes precludes the possibility of finding water at shallow depths. The Golden Gate Range, which is partly buried in the unconsolidated sediments on the east side of the valley, toward which the ground waters doubtless flow, should act as an underground barrier and cause an accumulation of ground waters, unless the rocks are too greatly fractured and fissured, on the Garden Valley side. This accumulation should produce an alkali tract in the lowest part of the valley, but there is no such alkali tract and no indication at the surface that shallow water exists beneath the valley.

The gap through which Cherry and Cottonwood creeks discharge is the place where the water from this valley is most likely to escape into Coal Valley. It is about one-fourth mile wide and is filled with unconsolidated sediments. A well reported to have been dug at Oneota, in Coal Valley, only a short distance south of the gap, to a depth of 250 feet failed to obtain ground water, indicating that if water escapes into Coal Valley through this gap it has not filled the sediments to within 250 feet of the surface.

It may be possible to find some water in Garden Valley along the course of Cherry and Cottonwood creeks at shallow depths. Water is frequently found in such places at depths much less than on lands more remote from the streams.

DRY LAKE VALLEY.

TOPOGRAPHY AND GEOLOGY.

Dry Lake Valley, a small basin with interior drainage lying northeast of Las Vegas Valley and traversed by the main line of the San Pedro, Los Angeles & Salt Lake Railroad, is bounded on the east by the Muddy Range and on the west by the Las Vegas Range (Pl. I). The Muddy Range is low, rising only about 2,000 feet above Dry Lake Valley, but the Las Vegas Range rises to a height of about 5,000 feet above the valley, or 7,000 feet above sea level. The Muddy Range consists mainly of Paleozoic limestone which dips steeply east; the Las Vegas Range is composed of limestone, shale, and quartzite which dip west. The southern boundary is formed by a rock divide that extends from the Las Vegas Range to the Muddy Range; the northern boundary, which was not seen at close range, appears also to be formed by a ridge of bedrock. The basin is thus apparently inclosed by bedrock. The unconsolidated sediments that underlie the valley are composed of clay, sand, and gravel. The alluvial slopes grade insensibly into the central flat, where a low, level, barren area of about 2 square miles forms a playa or "dry lake" which sometimes contains a few feet of water. On the west side of the valley some low hills project through the valley fill and shut off a gently sloping débris-filled basin which drains into the valley.

VEGETATION.

The native plants found in Dry Lake Valley are all of the drought-resistant type. Creosote is by far the most abundant plant. Considerable shadscale is interspersed among the creosote, and on the higher parts of the alluvial slopes some sagebrush is found. A small area surrounding the dry lake is fairly well covered with native grasses.

WATER SUPPLY.

At present the only water supply in the valley is that developed by the railroad company at Dry Lake station, $2\frac{1}{2}$ miles east of the central flat and 125 feet above it. At this station a well $11\frac{5}{8}$ inches in diameter and 461 feet deep was drilled. The material encountered in drilling was mostly clay with some bowlders interspersed. Water was found near the bottom and rose only to a level 284 feet below the surface, or fully 150 feet below the level of the central flat. The well has a capacity of 60 gallons per minute.

According to a vague report that could not be verified, a well at one time dug in the central part of the valley struck water only 60 feet below the surface. If this report is true, either the water table slopes toward the east or a shallow supply above the main body of

ground water was struck. Since most of the flood discharge into the valley no doubt comes from the lofty mountains on the west side, it is not improbable that the ground-water level descends toward the east. Nevertheless drilling projects in this valley should be based on the assumption that it will be necessary to sink to the level reached in the railroad well. The water in the railroad well at Dry Lake is corrosive, bad for boiler, only fair for domestic use and irrigation. The quality is shown in analysis 40 in the table opposite page 30.

INDIAN SPRING VALLEY.

LOCATION.

Indian Spring Valley lies west of the northern part of the Las Vegas Valley, from which it is separated by a low alluvial divide. This valley consists of a main part about 30 miles long from north to south and 4 to 6 miles wide and an arm that extends westward from the south end, thus giving a reversed L-shape to the valley as a whole. An alluvial divide at the west end of the arm separates the Indian Spring Valley from the Amargosa Desert. The Las Vegas & Tonopah Railroad crosses the south end of the valley.

TOPOGRAPHY.

Indian Spring Valley is bounded on the east by the Pintwater Range and on the west by the Spotted Range, these ranges being in a sense the northward continuation of the Spring Mountain Range, from which they are, however, separated by a débris-covered pass. At the north end of the valley these mountains are practically contiguous, being separated only by a high mountain pass that leads into the Emigrant Valley. The Indian Spring Valley is thus practically surrounded by mountains, and exhibits all the features of a Great Basin valley. The alluvial slopes are smooth and descend almost imperceptibly to the valley floor. The central part of the valley is low and flat and contains ancient shore features which show that it was once the bed of a lake. At its greatest extent this lake was about 18 miles long and 4 miles wide, had a maximum depth of about 100 feet, and was surrounded by a shore line about 45 miles in total length. The northern part of this ancient lake bed is now covered by a mud flat or "dry lake," which is at times covered with a few feet of water. (See Pl. I.)

GEOLOGY.

The bedrock formations exposed in the mountains surrounding this basin consist mainly of Paleozoic limestone, shale, and quartzite. The valley has been produced by the faulting of the older rocks, the strata in the mountains on each side of the valley having been up-

lifted with respect to those underlying the valley. The structure of the mountains was not studied except incidentally, but the rocks appear to dip away from the valley.

The unconsolidated sediments underlying the valley consist of sand, clay, and gravel. The depth to which they extend is not known, but the deepest well, which extends more than 600 feet below the surface, appears to end in them. The following log of the Ira MacFarland well, near Mesquite Springs, gives an adequate notion of the composition of the valley fill:

Log of Ira MacFarland well, three-fourths of a mile east of Mesquite Springs.

Sediments.	Thickness.	Depth.
	Feet.	*Feet.*
Sand, clay, gravel, and bowlders	55	55
Cemented gravel	23	78
Clay, sand, gravel, and bowlders in alternating layers 6 to 10 feet thick	32	110
Dark clay	18	128
Sand, clay, gravel, and bowlders in alternating layers 6 to 10 feet thick, becoming thinner with depth	230	358
Water-bearing stratum (water rose to 58 feet from surface)	......	358
Sand, gravel, and bowlders	142	500

VEGETATION.

The native vegetation in Indian Spring Valley consists chiefly of shadscale and creosote in the southern part and of creosote, yucca, and Spanish bayonet in the northern part. The slopes below Indian Spring and in the vicinity of Mesquite Springs, where the water table lies near the surface, bear a luxuriant growth of mesquite and sagebrush. The "dry lake," in the central part of the valley, is practically destitute of plants of any kind.

RAINFALL.

No rainfall data have been collected in this valley. The yucca and Spanish bayonet in the northern part indicate light rainfall. The lofty Spring Mountain Range has an important bearing on the precipitation in the southern part of the basin. The snow which falls on these mountains remains until late in the summer and begins accumulating again early in the fall. Storms are reported to gather frequently on the north slope of these mountains during the summer, and although few of them extend far into the valley they are, no doubt, the main source of the ground water in the southern part of the valley.

WATER SUPPLY.

Springs.—The valley contains a number of springs, one of the most important of which is Indian Spring, situated about a mile south of the Indian Spring depot. This spring issues from the

limestone at the foot of a large bluff and has a discharge of 0.91 second-foot and a temperature of 78° F. Its water is used mainly for irrigation on the ranch at the spring, but a part of it is conducted through a pipe line to the railroad and is used in locomotives. Several springs at the upper limit of the alluvial slope near the foot of the Spring Mountain Range are reported to have large discharges. One of these, the Cold Creek Spring, was visited in December, 1912, and was found to issue from a thick gravel bed, with a discharge of 1.95 second-feet. The discharge in the spring and early summer is reported to be more than twice this amount.

About 3 miles west of the Indian Spring depot there is a group of small springs, which, from the prevalence of mesquite trees, have been named Mesquite Springs. They are typical knoll springs, and the sandy mounds that mark their locations cover, perhaps, a square mile. Only a few of the mounds, however, now yield water, and the most copious have a discharge of only a few gallons a minute. It is notable that these knolls are directly in line with the large wash coming out of the Spring Mountain Range.

Quartz Spring is about a quarter of a mile from the foot of the mountains, in a canyon in the Pintwater Range, at the north end of the valley. It issues from quartzite and has a very small discharge. (See Pl. I.)

Wells.—Four wells, ranging from 100 to 700 feet in depth, have been drilled in Indian Spring Valley in search of artesian water. Their location, depth, and depth to the water level are in part shown on Plate I. These wells, although not successful in obtaining a natural flow, reached water which rose considerably above the levels at which it was found. The water rises nearest the surface in the tract adjacent to the lofty Spring Mountain Range.

The water table lies near the surface in the southern end of the valley, where three shallow wells have been dug. In a well about 100 yards west of Indian Spring and close to the foothills that lie in this part of the basin the water stands 16 feet below the surface. In the drilled well just south of the depot the water stands only 11½ feet below the surface, but the water level at this point is probably raised by the irrigation of the field just above it. In the well just north of the depot the water stands 37.8 feet below the surface and in the Ira MacCausland well, about one-fourth mile east of the depot, the water stands 46.4 feet below the surface.

QUALITY OF WATER.

The water in the Indian Spring Valley, as shown by analyses 34 to 38 in the table opposite page 30, is only moderately mineralized, the total solids ranging from 233 to 609 parts per million. Calcium is the most abundant base and bicarbonate the most abundant acid radicle.

The water is of good quality for domestic use and for irrigation, but it deposits considerable scale in boilers.

IRRIGATION WITH GROUND WATER.

Over a small area at the south end of the valley the conditions are favorable for obtaining water for irrigation by means of pumps, but there is little prospect of obtaining irrigation supplies from wells north of the isolated hills on the north side of the depot. Conditions do not appear favorable for obtaining flowing wells. The catchment area along the north side of the Spring Mountain Range is too small to supply the necessary head, and most of the water that falls on the alluvial slopes is diverted eastward into Las Vegas Valley.

RAILROAD VALLEY.

LOCATION AND AREA.

Railroad Valley is a structural trough lying between Quinn Canyon, Grant, and White Pine ranges on the east and Pancake and Reveille ranges on the west. It is about 100 miles long and 6 to 20 miles wide.

This valley and the regions draining into it cover about 6,000 square miles.

The writer spent only a brief time in this valley and saw only a part of it. When the field work was done it was not the intention to prepare a report on this valley, but as the published information in regard to it is very meager a brief description of it is given. The area examined is the part of the valley between Irwin's ranch and Locke and Willow Springs.

TOPOGRAPHY.

The topographic features exhibited in this valley are typical of those in the valleys of the Great Basin. The mountains surrounding the basin are high and precipitous. The valley proper is smooth and regular and has undergone few modifications within recent times.

There is good evidence that in former geologic times the valley held a lake of considerable size. Bars, beaches, and terraces not unlike those associated with present lakes are prominently developed. When it stood at its highest level the lake was about 75 feet deep and covered practically all the lower part of the valley. Locks and Blue Eagle Springs were near the shore and the sites of Horton and Irwin ranches were probably not more than a mile away from it. The locality of the so-called Potash well was covered by about 75 feet of water. About 3½ miles north of this well a very distinct gravel bar, on which the Ely-Tonopah automobile road is now located, was built by the waters of the lake. It runs practically straight east and west and was probably near the north shore of the lake. The

resemblance of this bar to a railroad grade probably suggested the name of the valley.

GEOLOGY.

The sedimentary rocks exposed in the mountains surrounding the basin are probably of Paleozoic age. The strata consists of limestone, shale, sandstone, quartzite, and gypsum, which have been modified in some places, especially about the Troy mining camps, by the interjection of igneous material.

The valley fill consists of sand, clay, and bowlders which extend to an unknown depth. The following log of the Potash well, sunk by the Railroad Valley Saline Co., in search of potash, shows the kind of material encountered in drilling as reported by the driller.

Log of Potash well, Railroad Valley.

	Feet.
Sand with occasional clay layers	1–32
Quicksand	32–103
Alternations of quicksand and clay. Artesian water, especially at 128 feet	103–132
White clay with small seams of fine gravel or coarse quicksand	132–136
Heavy clay	136–178
Quicksand. Artesian water	178–214
Alternations of clay and sand, layers 1 to 10 feet thick. Artesian water in most of the sands, especially at 220 and 250 feet	214–285
Sand, coarser in upper part. Pebbles 3 to 4 inches in diameter at 285 feet. Artesian water	285–305
Tough clay	305–336
Quicksand with some clay and some small gravel. Artesian water	336–340
Clay, with occasional streaks of quicksand	340–365
Quicksand with very small streaks of clay. Artesian water	365–375
Tough gray clay	375–390
Quicksand. Small artesian flow	390–391
Tough gray clay	391–418
Quicksand. Small artesian flow	418–419
Brown clay	419–429
Quicksand. Small artesian flow	429–430
Clay, gray in lower part, changing to brown in upper	430–460
Quicksand. Artesian water	460–461
Blue-green clay, with a white layer on top	461–470
Quicksand. Artesian water	470–471
Lead-colored clay	471–478
Very fine sand	478–479
White and blue-green clays	479–500
Blue-green clay with some coarse sand	500–504
White and blue-green clays	504–519
Quicksand. Artesian flow smelling of sulphureted hydrogen	519–520
Gray clay with occasional sand streaks. Small artesian flows in sands. All smell of sulphureted hydrogen	520–529

	Feet.
Gray clay	529–533
Very fine quicksand	533–534
Blue-green clay	534–539
Quicksand with some light-colored clay and some coarse gravel. Strong artesian flow	539–541
Yellowish, white, and blue-green clays	541–560
Quicksand. Artesian water	560–561
Blue-green and white clays	561–586
Quicksand. Small artesian flow	586–587
Clay	587–596
Alternations of sand and clay, the proportion of sand increasing downward. Small artesian flow at 605 feet	596–609
Clay, whiter in upper part	609–637
Quicksand	637–638
Tough clay, white and greenish in color	638–676
Quicksand. Small artesian flow	676–677
Alternations of clay and sand	677–680
White clay	680–691
Alternations of clay and sand	691–700
Clay, brownish on top	700–719
Sand	719–720
Brownish clay	720–738
Clay and quicksand mixed. Some coarse gravel. Very small artesian flows	738–746
Tough brownish clay	746–759
Sand alternating with very tough brownish clay. Very small artesian flows in the sands	759–771
Tough brownish clay	771–785
Quicksand. Artesian flow	785–786
Clay	786–790
Sandy streak in clay. Small artesian flow	790–791
Brownish clay	791–798
Alternations of clay and sand	798–805
Clay, hard and brown in lower part	805–816
Quicksand and gravel. Artesian water	816–822
Hard white clay	822–824
Clay and sand alternating every 2 to 6 inches. Proportion of clay increases with depth. Strong artesian flows in all sand strata	824–846
Brownish clay	846–850
Sand and gravel	850–855
Rapid alternations of clay and sand	855–865
Gray clay	865–876
Coarse gravel. Artesian water	876–878
Fine sand	878–882
Alternations of clay and sand	882–899
Gray clay	899–908
Sand and gravel. Strong artesian flows	908–924
Light-gray clay	924–934
Fine sand	934–941
Gray clay	941–945
Sand	945–947
Clay, yellow on top, gray below	947–967

	Feet.
Sand and gravel. Small artesian flow	967–969
Brown clay, a little sandy in upper part	969–1,002
Fine sand. Dry	1,002–1,003
Hard brown clay	1,003–1,049
Brown clay with a few very thin streaks of sand. Sands probably dry	1,049–1,085
Tough brown clay	1,085–1,131
Very thin sand streak. Dry	1,131
Brown clay	1,131–1,140
Sand cemented by calcium carbonate and gaylussite	1,140–1,144
Gray clay	1,144–1,165
Rapid alternations of clay and sand	1,165–1,175
Sand cemented by calcium carbonate. Characteristic lake-deposited tufa	1,175–1,190
Reddish clay with occasional very thin sand streaks	1,190–1,204
Bottom of hole, in quicksand	1,204

VEGETATION.

No rainfall observations have been made in Railroad Valley, but the native vegetation is to some extent an index of the amount of rainfall. The alluvial slopes are sparsely covered with shadscale, which is one of the most drought-resistant of the desert plants. The lowest part of the valley, where the water table lies near the surface, bears a much more luxuriant vegetation, the plants growing from 18 inches to 3 feet in height. They consist, however, mainly of greasewood, which will grow in soil having a comparatively high content of alkali. Salt grass grows abundantly on the slopes below Blue Eagle, Bullwhacker, and Willow springs. Quinn Canyon, Grant, and White Pine ranges produce an ample growth of mountain timber, but Pancake Range appears from a distance to be practically barren of vegetation.

SOIL.

The soil on the alluvial slopes is rich, and, where water is available for irrigation, produces good crops. No attempt has yet been made to farm the central part of the valley. The land between Irwin's ranch and the gravel bar does not appear to be strongly impregnated with alkali. Samples of the soil near the Potash well of the Railroad Valley Saline Co. and at the gravel bar were analyzed at the laboratory of the Nevada experiment station by Dr. S. C. Dinsmore, with the following results:

Analyses of soil from Railroad Valley, Nev. (percentage of total soil).

No.	Location.	First foot.			Succeeding feet.		
		CO_3.	HCO_3.	Cl.	CO_3.	HCO_3.	Cl.
1	Near Potash well	0	0.168	0.865	0	0.168	2.948
2	Salt marsh	0	.185	4.746			
3	Salt marsh-surface crust	1.750	.753	25.97			
4	Gravel bar	.106	.134	1.73	0	.084	.339
5	Near Blue Eagle Spring	0	.168	.035			

WATER SUPPLY.

Streams.—The principal streams entering the northern part of the valley are Duckwater and Kern creeks. The former was measured by engineers of the State engineer's office at Carson, Nev., in 1912, when the following discharges were obtained:

Discharge of Duckwater Creek, 1912.

Date of measurement.	Place of measurement.	Discharge.
		Sec.-ft.
Apr. 6	Weir No. 2, Stone mill; without overflow of Warm Spring	8.75
Apr. 7	Weir No. 2, Stone mill; with overflow of Warm Spring	10.37
Apr. 8	Weir No. 2, Stone mill; with overflow of Big Warm Spring	18.36
Apr. 6	Between Warm Spring and works	16.51
Apr. 7	At Mendes weir No. 3	16.10
Apr. 8	.....do	16.10

No measurements have been made of the discharge of Kern Creek, but about 500 acres are irrigated with the water which it supplies.

Ground water.—A large part of Railroad Valley appears to be underlain by shallow water. In the well near Blue Eagle Spring, in which the water level is not affected by the spring, the water stands 10 feet below the surface, and in the shallow well about three-fourths of a mile northwest of the Potash well the water stands 7 feet below the surface. In the John Sharp well, about 3 miles south of Blue Eagle Spring, the water stands less than 7 feet below the surface. The large area of alkali land indicates that the valley is underlain by shallow water, and the deep drilling done in search of potash salts confirms the indication. In the Potash well several flows of water were found. The owners reported that it was drilled to a depth of 1,204 feet below the surface and that about 25 horizons were found from which artesian water issued.

QUALITY OF WATER.

Three samples of water from this valley were analyzed by Dr. S. C. Dinsmore. The chemical character of the water is given in the table opposite page 30 (Nos. 31 to 33). The total solids range from 421 to 590 parts per million. Two of the waters, Nos. 31 and 33, are poor and the other is only fair for boiler use on account of their high content of scaling ingredients. They are fairly good for domestic use. Nos. 31 and 33 are of good quality for irrigation.

WATERING PLACES ON ROUTES OF TRAVEL.

RAILROADS AND STAGE CONNECTIONS.

The following information is given for the benefit of persons who are strangers to this region but who for any reason wish to make a journey to some part of it. In connection with these directions Plates I and II should be consulted. It should be borne in mind, however, that the routes of travel are subject to change, and the roads in use at this time may not be in use 10 years hence. For this reason the traveler should verify the information here given from local sources before starting on a long trip over a route on which there are few watering places.

The San Pedro, Los Angeles & Salt Lake Railroad, commonly known as the Salt Lake route, traverses the eastern and southern parts of this region. It crosses the Utah-Nevada State line at Uvada, and follows Clover Creek to Caliente, thence south along Meadow Valley Wash to Moapa, where it turns southwestward, and follows in general the old California trail over the Las Vegas Pass into Las Vegas Valley and southward. One branch extends northward from Caliente to Pioche, and another southward from Moapa to St. Thomas.

The Las Vegas & Tonopah Railroad extends from Las Vegas to Goldfield, where it connects, through the Tonopah & Goldfield Railroad, with the Southern Pacific system. It passes through the northern part of the Las Vegas Valley and the southern part of Indian Spring Valley.

A stage line is operated between Caliente and Delamar, the stage leaving Caliente on Mondays, Wednesdays, and Fridays, and returning Tuesdays, Thursdays, and Saturdays. This stage makes connections at Delamar with one operated between Delamar and Hiko, via Alamo. A stage runs between Moapa and Mesquite, leaving Moapa on Mondays, Wednesdays, and Fridays, and returning Tuesdays, Thursdays, and Saturdays.

MAIN ROUTES OF TRAVEL.

General considerations.—Any person intending to make a journey to an inland point will normally start from some railroad station, and the descriptions that follow are given accordingly. Supplies and equipment may be obtained at Caliente, Panaca, Pioche, Moapa, St. Thomas, and Las Vegas. Most of the so-called stations on the railroad are only switches where the trains pass and are without inhabitants, water, or shelter. The few inhabited stations, aside from the towns mentioned, offer at present no accommodations for travelers, and they should therefore not be depended upon for supplies other than water in emergency.

Pioche to Ely and Osceola.—From Pioche to Ely or Osceola the road traverses Duck Valley and crosses the divide leading into Spring Valley 6 miles north of Geyser. At the divide the road forks, the right-hand branch leading north to Osceola and the left-hand branch to Ely. Several good watering places are to be found along the road in the valley near Pioche and one about 30 miles north of Pioche near Poney Spring. The next water is at the Wambolt and Geyser ranches, 30 miles farther north. The roads north of Geyser were not traversed by the writer and information regarding the watering places should be obtained at this point.

Pioche to the White River and Railroad valleys.—Two main roads run from Pioche to Railroad Valley. The north road leads from Pioche to the White River valley and the northern part of Railroad Valley. From Pioche it leads northwestward past Royal and through Bristol Pass, where it turns west to Bristol well, thence northwest through Silver King Pass and into the south end of the White River valley, where it forks, one branch leading up the east side of the valley past Sunnyside, Emigrant Spring, Lund, Preston, and Barnes, and the other branch to Hot Creek ranch and beyond. From Barnes a road leads southwestward through the pass between White Pine and Grant ranges to Currant post office and other points. A road also runs directly from Emigrant Spring to Currant post office.

This north road from Pioche to Railroad Valley is favored with watering places. On the way to the White River valley water can be obtained at Bristol well, which is on the main road, and by making short detours, at Bailey Spring and Silver King well. In the White River valley water can be obtained at Sunnyside and at each of the places mentioned above. Water can also be had at several places in Railroad Valley.

The south road from Pioche to Railroad Valley crosses Stampede Gap about 10 miles west of Pioche, thence leads to Coyote Spring, in Bristol Valley, and thence southwestward across the Pahroc Range into the White River valley. In the ancient river channel of White River this road is joined from the south by a road from Hiko. It leads up the old river course about 10 miles, turns westward, crosses the Seaman Range and Coal and Garden valleys, and leads to Sharp post office. From Sharp the road leads up Cherry Creek across the pass between Quinn Canyon and Grant ranges and into Railroad Valley.

The only watering places along this road are at Coyote Spring and Sharp post office. If one is making the trip with a heavy load he will find it necessary to carry water between these two points. By going south on the Hiko road about 12 miles in the White River valley, White Rock Spring may be reached. This is a small seep

about a mile west of the road in the head of the canyon issuing from Seaman Range.

Pioche to Delamar, Hiko, and Alamo.—In going from Pioche to Hiko and Alamo one has a choice of three roads for part of the trip. One may go (1) by Bristol Pass, Bristol well, and Coyote Spring, and thence south through Bristol Valley, or (2) west through Stampede Gap, or (3) south across Pioche Range to Bennetts Spring and thence west through the pass between the Highland and Meadow Valley ranges and across Bristol Valley. These three roads unite at the south end of Pahroc Range, west of Bristol Valley, where the road turns west, crossing Pahroc Valley and the Hiko Range to Hiko. Alamo is 18 miles south of Hiko. The road from Pioche to Delamar passes Bennetts Spring and crosses the divide west of the Highland and Meadow Valley ranges. The road forks on top of the ridge, the right fork leading to Comet Canyon, the middle to Bristol Valley and Hiko, and the left fork southward to Delamar. One may, however, go into Bristol Valley and follow a road southward along the east side of the valley to Delamar.

The only watering places between Pioche and Hiko are at Bennetts, Bristol, Coyote, and Pahroc springs. Pahroc Spring is not on the main road, but is reached by a branch road about a mile long. (See Pl. I.) Water may be obtained on the eastern road to Delamar at Bennetts Spring, which is 13 miles from Pioche; at Cliff Spring, 17 miles from Bennetts; and at Grassy Spring, 13 miles from Cliff Spring. The western road to Delamar has no watering places after leaving Bennetts Spring. (See table of distances, p. 84.)

Caliente to Delamar, Alamo, and Hiko.—The road from Caliente to Delamar crosses the Meadow Valley Range and follows the west face of these mountains to Delamar. Water may be obtained at Oak Spring and Grassy Spring, which are nearly midway between Caliente and Delamar.

The road from Delamar to Alamo extends about 24 miles westward across Delamar Valley and the Hiko Range. There are no watering places along this road.

The road from Caliente to Hiko is the same as that to Delamar to a point near Oak Spring, where the road forks, the right-hand road running northwestward across the north end of Delamar Valley past Pahroc Spring, where it joins the road between Hiko and Pioche. Water can be obtained at Oak and Pahroc springs.

Hiko to Sharp post office and Railroad Valley.—The road from Hiko to Sharp post office leads up the valley 12 miles, and after passing through a rock canyon of the ancient White River it forks, the left branch turning to the northwest through the pass between Fossil Peak and Seaman Range into Coal Valley, and the right fork follow-

ing up the White River valley past White Rock Spring and north to Sunnyside. The Coal Valley road forks on the divide at the south end of Coal Valley, the right fork leading north across the east side of Coal Valley near Seaman Spring and north into White River valley, and the left fork leading northwest across Coal Valley past Oneota, where it turns westward, passing through a gap in the Golden Gate Range into Garden Valley, and runs to Sharp post office. The only water between Hiko and Sharp is at the Seaman Spring, where a small but reliable supply can be obtained. This is at the west pass of the Seaman Range and is in plain view from the valley. It is a short distance east of the east fork and several miles east of the west fork, but can be reached by several branches from both roads, as shown on Plate I.

From Sharp the road follows up Cherry Creek to the pass between Quinn Canyon and Grant ranges, thence northwest into Railroad Valley. Water may be obtained at Bardoli's ranch and at the Crows Nest Springs, where the road turns northward to Blue Eagle Spring.

Moapa to Alamo and Hiko.—The road from Moapa to Alamo and Hiko runs up Muddy Valley, Coyote Spring Valley, and Pahranagat Valley. The only water between Baldwin's ranch and Pahranagat Valley is at Coyote Spring.

Moapa to Bunkerville and Mesquite.—The road from Moapa to Bunkerville and Mesquite crosses the Mesa between Muddy and Virgin rivers. There are no watering places between Moapa and Bunkerville.

DISTANCES BETWEEN WATERING PLACES.

The following table gives the distances, in miles, between the chief watering places in southeastern Nevada. Some of the roads were not traversed and the distances given are only approximate.

Approximate distances, in miles, between watering places in southeastern Nevada.

	Barnes.	Bennett Spring.	Bristol well.	Caliente.	Coyote Spring, Bristol Valley.	Coyote Spring, Coyote Spring Valley.	Currant.	Delamar.	Dry Lake.	Geyser.	Hiko.	Indian Spring.	Las Vegas.	Logan.	Lund.	Moapa.	Overton.	Pahroc Spring.	Pioche.	Preston.	Seaman Spring.	Sharp post office.	Silver King well.	Sunnyside.	St. Thomas.	White Rock Spring.
Alamo.	128	64		54		32	123	24			18			77	115	67	82	34	77	120	41	73		84	90	42
Barnes.	0		83	136	81		28	120			110				10				103	6		80	67	43		87
Bennett Spring.		0						32		69	45							33	13							
Bristol well.			0		7		84	45			53				73			40	20	77		62	18	40		29
Caliente.				0		68	150	30	98	89	46		126	87	120	77	92	30	33	125	67	100			100	
Carp.				41					56	130			85	46		36	51		74						58	
Corn Creek Spring.												20	24													
Coyote Spring, Bristol Valley.					0			40			46				68			40	27	73		55	14	35		22
Coyote Spring, Coyote Spring Valley.						0		38			50			45	150	35	50			153	73	105		116	58	74
Currant.							0				105				34	188	203		100	30	82	50	68	44	213	88
Delamar.								0			30							20	45					75		
Dry Lake.									0	185			29	30		20	35		130						42	
Geyser.										0	115		215	175		165	180	100	56						188	
Hiko.											0			95	100	85	100	16	59	104	23	55		66	108	24
Las Vegas.												45	0	59		50	64		159						71	
Logan.																10	5		120						12	
Lund.															0				90	4			57	33		77
Mesquite.																35									32	
Moapa.																0	15		110	187	108	140		150	23	109
Overton.																	0		125						8	
Pahroc Spring.																		0	46		37	70		80		
Pioche.																			0	95			38	57	132	81
Preston.																				0			60	38		82
Seaman Spring.																					0	32				
Sharp post office.																						0		50		
Silver King well.																							0	24		
Sunnyside.																								0		44

INDEX.

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 365 PLATE I

Base compiled from plane-table sheets, topographic maps of U. S. Geological Survey, railroad alignments, and General Land Office data

MAP OF A PART OF SOUTHERN NEVADA

SHOWING GROUND-WATER CONDITIONS

By Everett Carpenter

Scale $\frac{1}{500,000}$

10 0 10 20 Miles

1914

LEGEND

Flowing well

Nonflowing well
Numbers in black indicate depth of well
Numbers in blue indicate depth to water level

Flowing-well area

Dry hole
Numbers in black indicate depth of hole

Approximate position of shore lines of ancient lakes
Lakes existed in Railroad and Duck valleys also, but their shore features were not mapped
Light broken blue lines indicate playas or alkali flats